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THE MARINE JURASSIC OF WYOMING AND SOUTH DAKOTA: ITS PALEOENVIRONMENTS AND PALEOBIOGEOGRAPHY

by

Robert Paul Wright

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Geology)
in The University of Michigan
1971

Doctoral Committee:

Professor Robert V. Kesling, Co-Chairman
Associate Professor Charles I. Smith, Co-Chairman
Professor John A. Dorr
Associate Professor Donald B. Macurda, Jr.
Professor Henry van der Schalie

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INTRODUCTION AND SCOPE

The Twin Creek Limestone in westernmost Wyoming and the Sundance Formation in Wyoming and the Black Hills of South Dakota are excellently suited for a paleoecologic and paleoenvironmental analysis based on the physical aspects of the sediments and their contained fauna. The strata include a wide range of lithologic types and faunal associations, reflecting a variety of depositional environments.

This investigation was concerned with deriving a representative picture of the various depositional environments and their contained faunas in relation to their diversity and community structure during Middle and Late Jurassic time.

The organisms studied include the marine Bivalvia, Foraminifera, and Ostracoda. The spatial distribution, relative abundance, and natural assemblages of the bivalves were determined. In addition, the habits and habitats of each bivalve taxon were studied by comparison of the fossils with closest living relatives (where possible), by functional considerations of hard parts and by noting burial positions. Diversity and abundance of the foraminifera and ostracods were used to establish possible fluctuations in salinity and water depth.

The field work involved the detailed measuring of twenty-two stratigraphic sections during the summers of 1968 and 1969. Bivalves and sediment samples were collected from these sections. The section locations are distributed over a wide geographic area, from the Black Hills of South Dakota to westernmost Wyoming (text-fig. 1). The first sections studied in the field were selected on the basis of their degree of completeness, accessibility, and geographic distribution. During the course of field work other sections were added to insure adequate coverage of the various depositional environments.

Bivalves were observed <u>in situ</u> prior to collection in order to

distinguish transported from relatively undisturbed assemblages. Channel samples were collected at regular intervals (see pl. 21 and 22 for location of samples)(at the time when sections were measured) and later were picked for foraminifera and ostracods (appendix E).

Text-fig. 1 explanation.

□ Section with written description in appendix B.

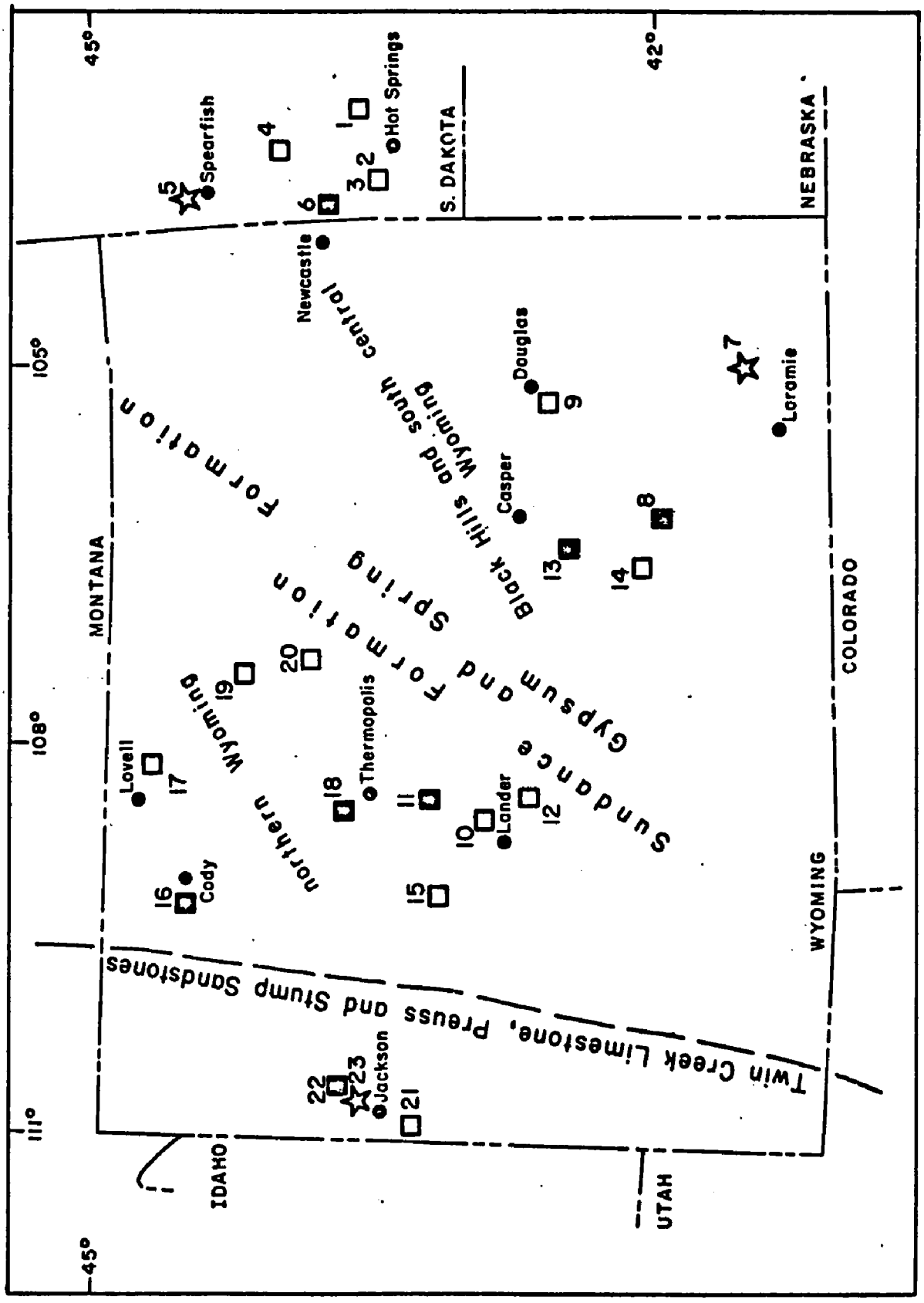
■ Sections with graphic section and written description.

☆ Sections mentioned in text only.

-- Geographic boundary between the Twin Creek Limestone, Preuss and Stump Sandstones in the west and the Gypsum Spring and Sundance Formations in the east.

Names of sections

1. Buffalo Gap
2. Minnekahta
3. Minnekahta
4. Rapid City
5. Spearfish
6. Newcastle
7. Farthing
8. Freezeout Mountains
9. Douglas
10. Lander
11. Maverick Spring Anticline
12. Vinceants Ranch
13. Alcova
14. Seminoe Dam
15. Bull Lake
16. Cody
17. Lovell
18. Thermopolis
19. Hyattville
20. Tensleep
21. Cabin Creek
22. Ditch Creek
23. Lower Slide Lake



Text-fig. 1 Index map showing distribution of stratigraphic sections and formations.

PREVIOUS GEOLOGICAL WORK IN THE REGION

Geologic exploration began in Wyoming and South Dakota in the 1850's. Meek & Hayden (1858) first described the Jurassic sediments and fossils in the Black Hills. They later (1860, 1865) figured and described more fossils that had been collected from the Black Hills by the Exploring Expedition of G. K. Warren and F. V. Hayden in the Upper Missouri Country. They described the bivalve Gryphaea nebrascensis Meek & Hayden, a very characteristic fossil of formations later to be named the Twin Creek Limestone and the Sundance Formation. Their specimens had been brought back from the Wind River Valley in Wyoming by Captain Reynolds, one of the early explorers in the Northwest Territories. The Hayden Survey between 1868 and 1877 established the widespread distribution of marine Jurassic throughout South Dakota, Wyoming, and Idaho.

In 1899 Stanton described the Jurassic bivalves from Yellowstone National Park and attempted to correlate the Jurassic sediments of Wyoming with those in Utah and South Dakota on the similarities of contained fossils.

In the same year Darton applied the name Sundance Formation to the sequence of marine Jurassic sediments in the Black Hills. This was the first attempt to classify the sediments in the Black Hills and was substantiated with measured sections and faunal lists.

Veatch (1907) named the fossiliferous marine Jurassic sediments exposed on Twin Creek between Sage and Fossil, in southwestern Wyoming, as the Twin Creek Formation.

Imlay (1945) stated that Middle Jurassic rocks of Bajocian and Bathonian age definitely occur in the Western Interior. The ammonite Stemmatoceras occurring in the Twin Creek Limestone in southeastern Idaho established a Bajocian (lowest Middle Jurassic) age. Imlay assigned a Bathonian age to certain exposures in Wyoming. In most

earlier papers, the Twin Creek and Sundance strata had been regarded as entirely Late Jurassic in age.

During the years from 1947 until 1967, Imlay designated member names for the Twin Creek Limestone and Sundance Formation in Wyoming and South Dakota (text-fig. 2), described the distribution, lithology, thickness, faunal content, contact relationships, and age of each of the members (text-fig. 4).

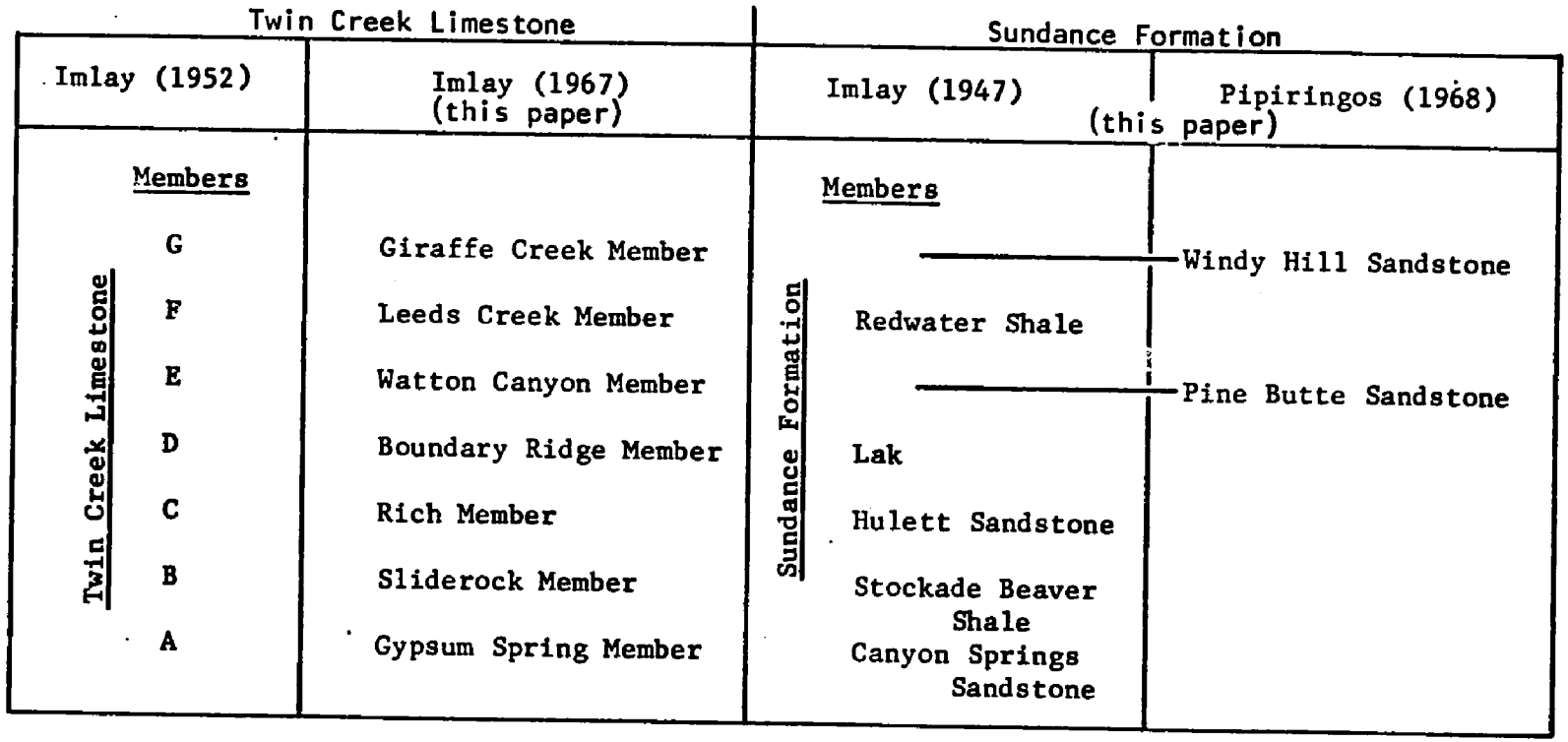
Pipiringos (1968) designated the Pine Butte and Windy Hill Sandstone as two new members of the Sundance Formation in south-central Wyoming (text-fig. 2). The Pine Butte member occurs between the Lak and Redwater Shale Members. The Windy Hill Member was previously included in the bottom of the Morrison Formation.

Imlay's (1947) discussion of the marine Jurassic in the Black Hills was the first detailed work since Darton's presentations (text-fig. 2). He correlated the Canyon Springs Sandstone, Stockade Beaver Shale, and Hulett Sandstone with the "Lower Sundance" Formation on the similar occurrence of Arcticoceras henryi (Meek & Hayden).

Imlay (1948, 1953, 1967) established ammonite zones in the Western Interior marine Jurassic which served as a basis for correlation of the marine Jurassic rocks of Wyoming and South Dakota (text-fig. 4). Taxonomic analyses of the marine Jurassic microfossils of Wyoming and South Dakota (Loeblich & Tappan, 1950a; Loeblich, 1950; Peterson, 1954a; Swain & Peterson, 1951, 1952) served as the source for my microfossil identifications.

Loeblich & Tappan discussed the occurrence of foraminifera from the Sundance Formation in Wyoming and South Dakota. Peterson & Swain described species of ostracodes from the Sundance Formation of Wyoming, South Dakota, and the Rierdon Formation of Montana.

Peterson (1954b) described the stratigraphy of the Sundance Formation in the Powder River Basin in eastern Wyoming and relationships with the marine Upper Jurassic sediments elsewhere. He proposed that the Sundance Formation be raised to group rank comprising



Text-fig. 2 Evolution of stratigraphic nomenclature.

two formations equivalent to the Rierdon and Swift Formations in Montana.

Peterson (1957) considered the influence of major negative (Twin Creek trough and Williston Basin) and positive (Belt Island and Sheridan Arch) tectonic elements on the patterns of sedimentation within the Jurassic seaways. These tectonic elements had a definite influence on the distribution of lithofacies and biofacies.

REGIONAL GEOLOGIC SETTING

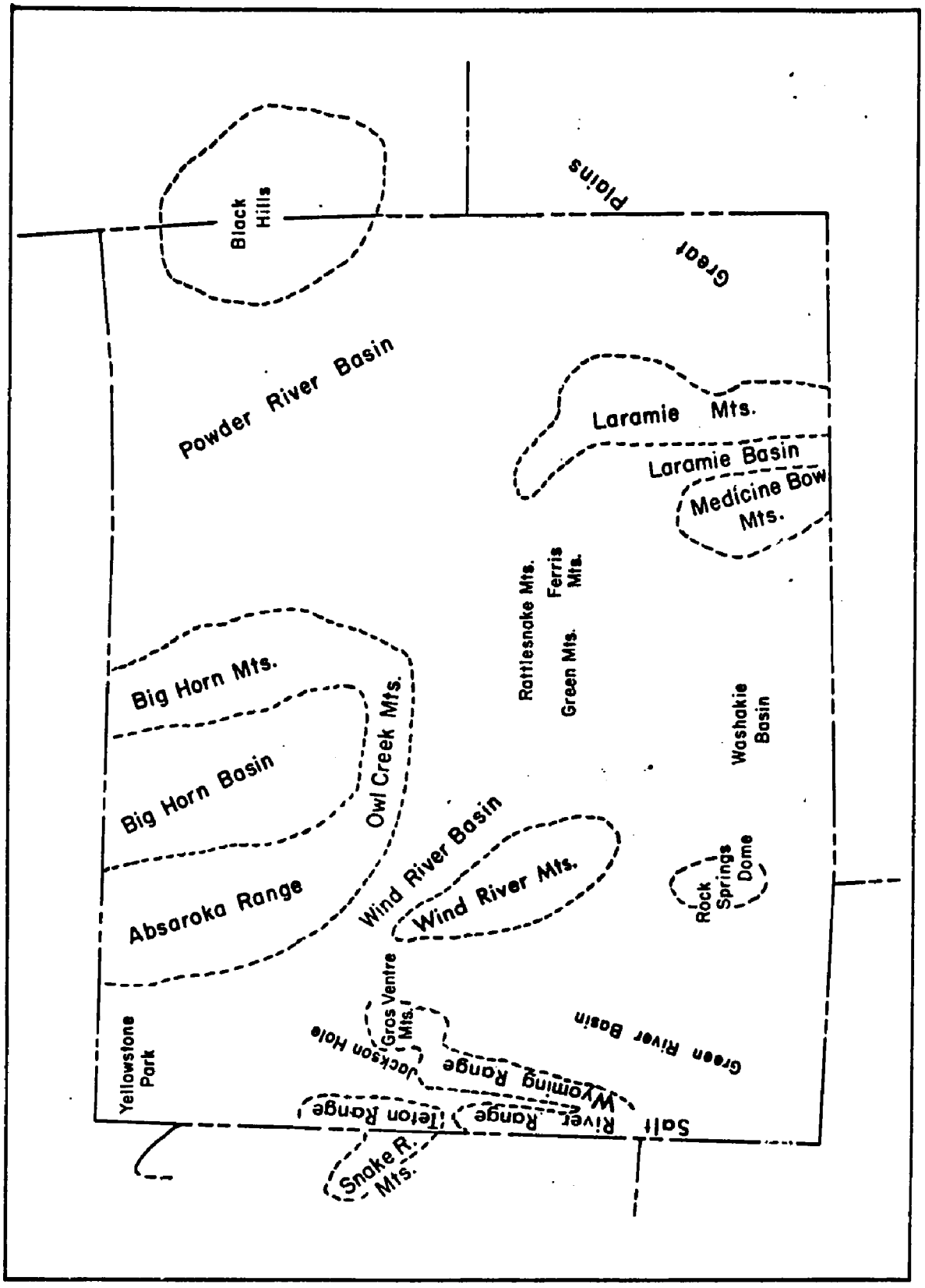
The area studied is set in the heart of the Rocky Mountains (text-fig. 3). A youthful and rugged topography includes numerous peaks reaching altitudes over 12,000 feet and standing 7,000 feet above basin floors. Grand Teton in the Teton Range and Ganett Peak in the Wind River Range are 13,747 feet and 13,785 feet in elevation respectively (Eardley, 1962).

The Snake River Mountains, Salt River Range, Wyoming Range, Teton Range, and Gros Ventre Mountains form the rugged topography in western Wyoming and thrust faults formed during the Laramide phase of the Cordilleran orogeny characterize this area. Some of the major thrusts include the Absaroka, St. John, Darby, Grizzly and Cabin, and Prospect-Cliff Creek. They were thrust eastward and now trend predominantly north-south.

Associated with the thrusts and other major faults are thick clastic deposits such as the Paleocene-Eocene Hoback Formation and the Eocene Pass Peak Formation representing the products of rapid erosion of the surrounding highlands produced during the Laramide phase.

East of the thrust zone is the Absaroka Range, Big Horn Mountains, Owl Creek Mountains, Wind River Mountains, Laramie Mountains, and Black Hills. Separating the mountains are basins filled with Tertiary sediments. The main basins are the Powder River, Big Horn, Green River, and Wind River. Paleozoic and Mesozoic sediments, covered by the Tertiary basin deposits, are exposed along the flanks of the mountains.

For the most part, the mountain ranges trend northwest-southeast, are asymmetrical, and have cores of exposed Precambrian rock. The Absaroka Mountains is an exception, being largely composed of volcanic flows, pyroclastics, and small plutons.



Text-fig. 3 Location of major mountain ranges and basins in Wyoming and adjacent areas.

STRATIGRAPHY

General

Several formational names have been used to describe the Middle and Upper Jurassic marine sediments in Wyoming and South Dakota (Imlay, 1956; Peterson, 1957). This is because distinct mappable lithologic units are not laterally continuous throughout the entire state of Wyoming.

The Twin Creek Limestone (a thick sequence of predominantly limestone) occurs in western Wyoming (text-fig. 1). It is Middle and LateJurassic in age. The Twin Creek Limestone contains seven members (text-fig. 4) which are, from bottom to top: Gypsum Spring Member, Sliderock Member, Rich Member, Boundary Ridge Member, Watton Canyon Member, Leeds Creek Member, and Giraffe Creek Member. The first four members can be correlated with the Gypsum Spring Formation in south-central and northern Wyoming and the Black Hills of South Dakota. The upper three members can be correlated with part of the "Lower Sundance" in northern Wyoming, and with the first three members of the Sundance Formation in the Black Hills and south-central Wyoming (text-fig. 4).

Overlying the Twin Creek Limestone are sandstones referred to as the Preuss Sandstone and the Stump Sandstone. They are late Jurassic in age and can be correlated with the middle and upper part of the Sundance Formation.

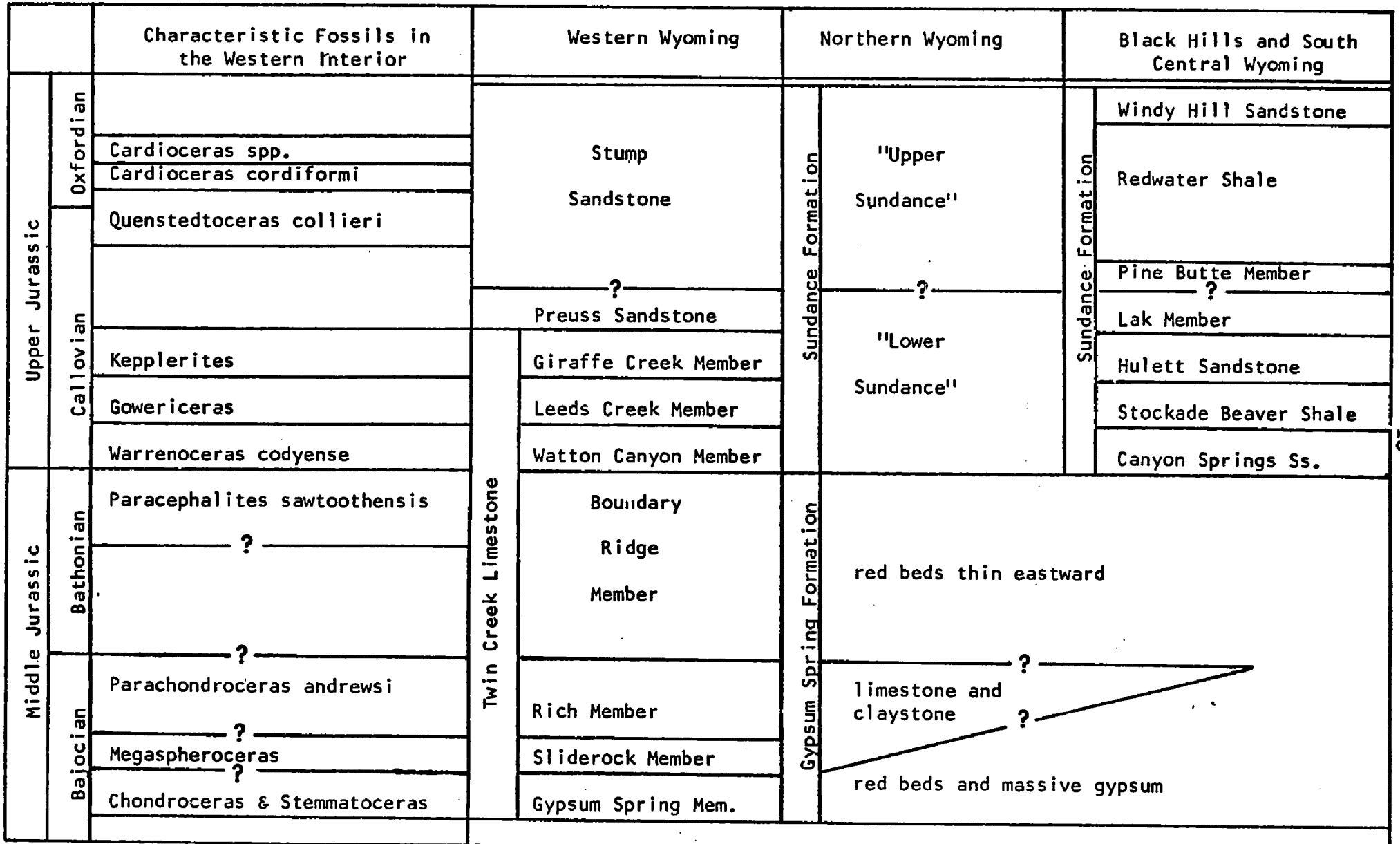
The Middle Jurassic rocks exposed throughout most of Wyoming and the Black Hills of South Dakota are referred to as the Gypsum Spring Formation. In northern Wyoming this formation contains a lower redbed and gypsum member, a middle claystone and limestone member, and an upper redbed member. In central and eastern Wyoming and the Black Hills, gypsum and redbeds persist but the middle claystone and limestone member thins greatly and is absent at some localities.

The Upper Jurassic rocks exposed throughout most of Wyoming are here referred to as the Sundance Formation. In south-central and western Wyoming the Sundance contains seven distinct members. They are from bottom to top: Canyon Springs Sandstone, Stockade Beaver Shale, Hulett Sandstone, Lak Member, Pine Butte Member, Redwater Shale, and Windy Hill Sandstone. Each member varies in thickness, composition, and color, and is easily recognizable.

In northern Wyoming distinct units typical of the Canyon Springs Sandstone, Hulett Sandstone, Lak Member, Pine Butte Member, and Windy Hill Sandstone are not recognizable. Because of this, Imlay (1956) used the names "Lower Sundance" and "Upper Sundance" Formations for those deposits which in part resemble and are laterally equivalent to the seven members of the Sundance Formation in south-central and eastern Wyoming. Peterson (1957) on the other hand considered the deposits of the "Lower Sundance" and "Upper Sundance" Formations in northern Wyoming to be more similar to the correlative Rierdon and Swift Formations in Montana than to the Sundance Formation in south-central and eastern Wyoming and the Black Hills, and referred to them as such.

For the sake of nomenclatural simplicity and clarity, the northern Wyoming rocks are herein called the Sundance Formation. The "Upper Sundance" and "Lower Sundance" Formations of Imlay (1956) are used here as informal names, each made up of distinct mappable lithologic members.

The correlation chart (text-fig. 4) presented here is adapted from Imlay (1948, 1953, 1967) with some modification. Correlation is on the basis of distinct ammonite zones and closely asscciated bivalves. Of particular importance is the interpretation of the contacts between the Gypsum Spring Formation and Sundance Formation, between the Preuss and Stump Sandstones, between the "Lower Sundance" and "Upper Sundance," and between the Lak or Pine Butte with the Redwater Shale Member of the Sundance Formation. Most students of the Middle and



Text-fig. 4 Correlation chart of marine Jurassic in Wyoming and South Dakota. Modified after Imlay (1948, 1953, 1967).

Upper Jurassic in Wyoming contend that major disconformities exist between the above-mentioned units.

Concerning the contact between the Gypsum Spring Formation and the Sundance Formation, Imlay (1956) suggested that the Gypsum Spring Formation is truncated unit by unit southward along the east side of the Big Horn Basin, and from west to east along the south side of the Big Horn Basin, by the Sundance Formation.

Pipiringos (1968, fig. 2) has interpreted the Gypsum Spring Formation as being truncated by the Sundance Formation from Lander, Wyoming, where the Gypsum Spring Formation is about 200 feet thick to Happy Spring, about 45 miles southeast of Lander where the formation is about 20 feet thick.

The following evidence has been used to infer the presence of a disconformity between the "Lower Sundance" and "Upper Sundance." In Montana, Quenstedtoceras collieri is found to occur 25' to 30' above the base of the Swift Formation (Imlay, 1948), which is the time equivalent of the "Upper Sundance" in northern Wyoming (text-fig. 4). Kepplerites mclearni occurs in the upper 10' or 15' of the Rierdon Formation (Imlay, 1948) of Montana, which is time equivalent of the "Lower Sundance" in northern Wyoming. Quenstedtoceras collieri and Kepplerites mclearni are late and early Callovian respectively (Imlay, 1948). The conclusion is that middle and most of upper Callovian deposits are absent and represented by a major disconformity.

Concerning the Wyoming area, Imlay (1947, p. 257) states: "A disconformable relationship with the overlying Redwater Shale Member is indicated by abrupt change from unfossiliferous red beds [of the Lak] to highly fossiliferous sandstone and shale and possibly by marked local variations in thickness of the Lak Member." In the Big Horn Basin of north-central Wyoming, the disconformity is supposedly indicated by passing from non-glauconitic shale or fine-grained sandstone or sandy limestone to highly glauconitic coarse-grained impure sandstone and shale (Imlay, 1947, p. 258).

Peterson (1954) states, "In other areas of occurrence [other than the Williston Basin], the Rierdon is apparently overlain disconformably by the Swift Formation. Where the 'Sundance red' or Lak beds are present, such a relationship is suggested by the consistently sharp change from redbeds to overlying clean, glauconitic marine sandstone or silty shale of the Swift. The widespread oolitic sandy to pebbly coquina at the top of the Rierdon in the Big Horn mountains is evidence for a submarine disconformity in that area."

Peterson also suggests (p. 487) that the change in the different kinds of bivalves and ostracods in the Rierdon and Swift Formation supports the existence of a disconformity.

Pipiringos (1968, p. 23) states that the "basal bed of Redwater Shale Member lies sharply on the underlying rocks on a surface of regional disconformity"; and "The Redwater Shale Member locally truncates the Pine Butte Member."

It is my contention (discussed in the text) that disconformities representing substantial, lengthy periods of time from part of the Bathonian to Callovian (between "Upper Sundance" and "Lower Sundance"; and between Lak or Pine Butte and Redwater Shale) do not exist.

Abrupt vertical change in lithology (e.g., Lak to Pine Butte or Redwater Shale), lateral pinching out of beds (e.g., Pine Butte Member), and the occurrence of sedimentary particles like oolites and scattered fossil fragments (e.g., near top of "Lower Sundance"; the Pine Butte Member) may represent temporal environmental response rather than evidence for a major disconformity.

The excellent biostratigraphic work done by Imlay in the Western Interior, without which environmental interpretation would be impossible, has been carefully considered. Nevertheless, the occurrence of different age ammonites (i.e., Kepplerites mclearni and Quenstedtoceras collieri) separated by intervening sediments devoid of ammonites of an intermediate age does not substantiate the existence of a disconformity. Students of the Jurassic in Wyoming have disproved the existence of major disconformities. John Green (Masters Thesis) has shown that a major

disconformity does not separate the Gypsum Spring Formation and Sundance Formation in the Wind River Basin as proposed by Pipiringos (1954).

Mary Hileman (Masters Thesis) has shown that a disconformity does not separate the Preuss and Stump Sandstones.

The Sundance Formation is overlain conformably by the Morrison Formation. At some locations the base of the Morrison is white lenticular sandstone (Freezeont Mountains, pl. 15), variegated shale (Bull Lake) or gray shale (Alcova, pl. 14). The contact is often difficult to place because the sediments of the Morrison are often gradational with those of the Sundance. At Alcova and Farthing for instance the occurrence of fresh water ostracods was used to indicate the beginning of the Morrison Formation.

Gypsum Spring Formation

The Gypsum Spring Formation underlies the Sundance Formation in the Black Hills and throughout central and northern Wyoming (Pl. 20 and 21). In northern Wyoming it contains a lower gypsum and redbed member, a middle claystone and limestone member, and an upper redbed member (pl. 18). Throughout the rest of Wyoming the gypsum and redbeds persist but the middle claystone and limestone member thins greatly or is absent (Imlay, 1956). Imlay referred to the sequence of gypsum and redbeds, limestone and claystone, and redbeds at Cody as the Piper Formation. He (1956) referred to the sequence of gypsum, limestone, and redbed deposits along the Bighorn Mountains from Lovell south to Thermopolis as the Gypsum Spring Formation. This was done because the middle limestone and claystone unit at Cody is more fossiliferous and thicker than the same unit of the Gypsum Spring Formation. This author includes the Cody exposures within the Gypsum Spring Formation because the sediments in both areas reflect similar environments of deposition and are genetically related.

The middle claystone and limestone member at Cody is about 50 feet thick (pl. 21). It is abundantly fossiliferous and time equivalent to

the Sliderock and Rich Members of the Twin Creek Limestone. The eastward changes in the marine fauna from these members of the Twin Creek Limestone to the Gypsum Spring Formation are discussed on page 59 (see pl. 21).

At Cody (pl. 18) the middle member is predominantly greenish-gray shale interbedded with thin oolitic limestone beds and several gypsum beds. The limestone beds are predominantly poorly washed biosparites with pellets, oolites and intraclasts (pl. 2, fig. 1). The absence of mud or silt matrix is indicative of the turbulent bottom conditions that existed at the time of deposition of these beds.

Along the eastern and south sides of the Bighorn Basin, the middle fossiliferous unit becomes dolomitic, laminated, crinkled, or vuggy and individual limestone beds thin greatly (Imlay, 1956). The lower gypsum and upper red shale units persist (pl. 20). Imlay (1956) interprets the upper contact of the Gypsum Spring Formation along the east and south sides of the Big Horn basin as unconformable with the Sundance Formation. He suggests the Gypsum Spring Formation is truncated unit-by-unit at the contact from north to south. One of the units supposed to have been truncated is a limestone containing molds of small bivalves associated with green or greenish-yellow stains that occurs in the middle member of the Gypsum Spring Formation. This unit was found by Imlay (1956) in the Gypsum Spring Formation throughout northern Wyoming.

Detailed stratigraphic analysis of the Gypsum Spring Formation in the Wind River Basin by Green (Masters Thesis) indicates the persistence of a fossiliferous horizon that is a greenish-stained shaly limestone containing small bivalves, possibly Tancredia or Astarte.

The persistence of this "green-stained" fossiliferous bed throughout southern exposures of the Gypsum Spring Formation tends to discredit the existence of a major disconformity between the Gypsum Spring Formation and the overlying Sundance Formation.

Reconsideration of the regional distribution of the Gypsum Spring

sediments in conjunction with Green's (Masters Thesis) work in the Wind River Basin indicates that lateral changes in lithology of the Gypsum Spring Formation from the Cody area southward to the Wind River Basin may not be due to post-depositional truncation. Rather, the sediments reflect a variety of depositional environments. Semi-restricted hypersaline lagoons (text-fig. 9), in which deposition of the lower gypsum and redbed member and upper redbed member took place, were periodically flushed with normal marine water in northern Wyoming, which resulted in the development of the thick middle member of claystone and limestone. Persistent hypersaline lagoons and infra-tidal and supratidal environments in the Wind River Basin resulted in nondeposition or thin deposits of the middle member.

Sundance Formation of the Black Hills and South-Central Wyoming

Canyon Springs Sandstone Member.-- The Canyon Springs Sandstone Member was originally defined by Imlay (1947) and redefined by Pipiringos (1968). It is present in the southern part of the Black Hills and throughout south-central and eastern Wyoming (pl. 20). In the Black Hills, as exposed at Minnekahta, it forms a resistant ledge of white sandstone overlying the salmon-colored massive sands of the Nugget ? and underlying sandy oolite and gray shale of the Stockade Beaver Shale (pl. 1, fig. 1). A close-up photograph (pl. 3, fig. 1) shows the thin beds of the Canyon Springs Sandstone containing irregular stringers of broken oyster shells. At Buffalo Gap the member is more varied, containing maroon shale and salmon colored sandstone. The sandstone is burrowed and cross-bedded.

Throughout south-central Wyoming the member contains a lower unit of massive cliff-forming cross-bedded sandstone and an upper unit of thin-bedded rippled oolitic sandstone (pl. 1, fig. 2; pl. 15). The member at Alcova (pl. 20) is overlain by the Stockade Beaver Shale but further to the south at Freezeout Mountains and Seminoe Dam, the Canyon Spring Sandstone is directly overlain by Hulett Sandstone, because the Stockade Beaver Shale is not present this far south. The

Canyon Spring Sandstone in part represents a southern sand facies of the Stockade Beaver Shale. The two members are laterally gradational in the Rattlesnake Hills (Pipiringos, 1968).

An interesting feature of the Canyon Spring Sandstone are chert pebbles, which are generally concentrated at the base of the lower massive sandstone unit (Freezeout Mountains) or the base of the upper platy sandstone unit where the lower sandstone unit is absent (Pipiringos, 1968) (Alcova). These chert pebbles are also found at the base of the Stockade Beaver Shale in the Lander, Wyoming area where the Canyon Spring Sandstone is absent (Bull Lake and Vinceant Ranch) and are also present at the base of the Stockade Beaver Shale in the Black Hills where the Canyon Springs Sandstone is present (Minnekahta).

Pipiringos (1968) has interpreted this chert horizon as marking a period of major, regional uplift and erosion after the deposition of the Gypsum Spring Formation and prior to the deposition of Stockade Beaver Shale and Canyon Spring Sandstone. He interprets the chert as lag gravels from erosion of a large section of lower Jurassic and Triassic strata. The chert pebbles represent the initial high energy deposit formed during transgression of the sea across the Wyoming platform in early, according to John Green (Masters Thesis), Callovian time (text-fig. 10) after deposition of the Gypsum Spring Formation. The Gypsum Spring Formation onlaps the Nugget Sandstone and was not uplifted and truncated as proposed by Pipiringos.

The Canyon Spring Sandstone seems to represent massive dune sands (lower unit) and beach sands (upper unit), the latter loosely cemented, very calcareous, and containing current or wave deposited stringers of oyster shells. Its geographic distribution throughout south-central and eastern Wyoming and the Black Hills and lateral gradation with the Stockade Beaver Shale in the Rattlesnake Hills (Pipiringos, 1968) suggests that it represents a near shore to terrestrial facies of the Stockade Beaver Shale along the southeastern shoreline during early Callovian time.

Stockade Beaver Shale Member.-- This member is used here as defined by Imlay (1947) for shale exposures in the Black Hills and by Pipiringos (1968) for shale exposures throughout south-central Wyoming (pl. 20). The same shale unit passes northward and occurs throughout the Bighorn Basin, where it makes up the middle shale member of the "Lower Sundance" (pl. 21).

The Stockade Beaver Shale occurs stratigraphically above either the Canyon Spring Sandstone or Gypsum Spring Formation where the Canyon Spring Sandstone is absent and below the Hulett Sandstone.

In the Black Hills, the member varies in thickness from about 64 feet at Rapid City to about 5 feet at Buffalo Gap. The predominant lithology is gray shale, but in the upper part of the member there are interbeds of thin-bedded sandstone marked by burrows and oscillation and interference ripples (pl. 13). These sandstone beds contain bivalve shell fragments that were current deposited (pl. 2, fig. 5). The interbedded shale and sandstone is well exposed at Rapid City (pl. 1, fig. 3) where the sandstone beds in upper part of the member grade upward into the overlying Hulett Sandstone.

The sandstone that occurs in the upper part of the Stockade Beaver Shale in the Black Hills does not extend east of the Black Hills (pl. 20). The sandstone beds indicate the close proximity of the eastern shoreline in the Black Hills.

Farther west at Douglas (pl. 1, fig. 4) and Alcova the Stockade Beaver Shale is easily recognizable just above the massive, white sands of the Canyon Spring Sandstone. Here, medium-gray shale predominates, but near the top of the member the shale becomes sandy and is commonly burrowed (pl. 14); the unit may contain several thin beds of lenticular sandstone that are also burrowed.

To the south in the vicinity of Seminoe Dam and the Freezeout Mountains the member is not present. It is absent as far west as the Green Mountains (Pipiringos, 1968). The southern limit of Stockade Beaver Shale deposition apparently was just north of these southern

outcrops and south of Alcova.

The lithology of the Stockade Beaver Shale is more varied at Bull Lake and Maverick Springs. At these localities the typical gray shale of the member is underlain by a thick sequence of limestone and sandstone (pl. 20) containing oolites, pellets and clasts up to 8 inches in diameter (Green, Masters Thesis) interbedded with claystone and shale. A bored surface is present at the top of the sequence at Vinceants Ranch (pl. 7, fig. 1). This bored surface indicates that the lime muds at Vinceant Ranch underwent submarine or subareal lithification prior to being bored by clams.

At Bull Lake the lower part of the member includes rock types such as sandy oosparite (pl. 2, fig. 4), containing broken shell fragments and stringers of chert pebbles, biopelmicrite, poorly washed oopelsparite, and claystone.

At Maverick Spring (pl. 16) the lower oolitic sequence of the Stockade Beaver Shale consists of a variety of limestone (biopelmicrite, pl. 2, fig. 3; oobiosparite, pl. 2, fig. 2; and biosparite) and sandstone interbedded with claystone and shale. The limestone is burrowed, and contains bivalve, gastropod, bryozoan, and echinoderm fragments as well as bivalves in living position. The overlying shale is 60 feet thick and has the characteristic medium-gray to olive-gray color of the member as found in southeastern Wyoming and the Black Hills. Its contact with the overlying Hulett Sandstone is sharp but conformable.

Sedimentary grains such as oolites and shell fragments in the lower oolitic sequence of the Stockade Beaver Shale indicates turbulent water conditions in the Maverick Springs and Bull Lake area.

The lower oolitic sequence at these localities represents high energy deposits formed during early Callovian time when the water deepened over the Wyoming shelf during transgression.

Hulett Sandstone Member. -- The Hulett Sandstone is the third member of the Sundance Formation. It forms relatively resistant sandstone ledges overlying the Stockade Beaver Shale or the Canyon Springs

Sandstone where the Stockade Beaver Shale is absent and underlying the Lak Member or Redwater Shale where the Lak is absent. Its lower and upper contacts with these members are conformable.

The member has a wide geographic distribution from the Black Hills in the east, westward throughout south-central Wyoming (pl. 20). A similar sandstone unit is present in northern Wyoming and is the upper sandstone member of the "Lower Sundance" (pl. 21).

In the Black Hills the Hulett Sandstone varies in thickness from a little over 25 feet at Rapid City to about 56 feet at Newcastle (pl. 13). The thin- to medium-bedded sandstone is oscillation and interference ripple-marked (which shows several sets of directions), cross-bedded, and centrally furrowed trail-marked (pl. 3, figs. 2-4; pl. 4, fig. 1). Shale interbedded with the sandstone is commonly mottled maroon.

Pipiringos (1968) uses the presence of the centrally furrowed trail-marks to define the top of the Pine Butte Member. This tends to be misleading because they are not restricted to that member but are common in the Hulett Sandstone wherever bedding planes are exposed.

In southeastern Wyoming in the vicinity of Freezeout Mountains and Seminoe Dam (pl. 20) the Hulett Sandstone rests directly on Canyon Spring Sandstone (pl. 4, fig. 3). The Stockade Beaver Shale was not deposited this far south. The Hulett Sandstone at Freezeout Mountains (pl. 15) forms relatively resistant beds of fine-grained, oscillation-rippled sandstone that is slightly cross-bedded near the top. The Hulett beds overlie coarse-grained, rippled sandstone of the Canyon Springs Sandstone.

At Maverick Spring (pl. 16) the sandstone is locally burrowed, oolitic, and has oscillation ripple-marks with the distance between crests being as much as 3 feet. The top of the Hulett here is strongly festoon cross-bedded in sets 1-2 feet thick with plan-view width of up to 4 feet. Current direction is predominantly north-south (pl. 4, fig. 2; pl. 7, fig. 4). Bedding planes are often covered with trail-marks.

The Hulett Sandstone characterized by oolites, oscillation and

current ripples, cross-bedding (including festoon), trail-marks, and burrows, represents shallow water deposits that formed throughout south-central and eastern Wyoming and the Black Hills. The water may have been only a few feet to several tens of feet deep as shallowing occurred across the Wyoming shelf following deposition of the Stockade Beaver Shale. This shallowing of the shelf must have been due to general uplift affecting the entire shelf because similar sandstone of the "Lower Sundance" was deposited in northern Wyoming as well as sandstone, red siltstone, and oolitic sandy limestone of the Giraffe Creek Member of the Twin Creek Limestone in western Wyoming and southeastern Idaho.

Lak Member.-- The Lak Member is used as defined by Imlay (1947) for reddish-brown siltstone, sandy siltstone, and silty sandstone occurring in the Black Hills. The member is also present throughout south-central and eastern Wyoming (pl. 20), where at some localities it may lose its reddish-brown to salmon color and be white to light tan in color (pl. 5, fig. 2) and contain gypsum (pl. 14).

Its contacts are conformable with the Hulett Sandstone below and the Pine Butte Member or Redwater Shale above. The gradational lower contact with the Hulett Sandstone is well exposed at a roadcut just south of Rapid City where yellow sandstone and alternating gray and maroon shale of the Hulett Sandstone pass upward into red siltstone of the Lak (pl. 4, fig. 4).

At Newcastle (pl. 13) about 45 feet of salmon-colored siltstone of the Lak Member overlies and is gradational with greenish-gray sandy shale of the Hulett Sandstone. The upper contact with the Pine Butte Member is gradational and the sequence goes from interbedded soft sandy greenish-gray and red siltstone and thin beds of shale in the upper part of the Lak to 15 feet of white soft sandstone in the Pine Butte Member (pl. 13). Its upper contact with the Pine Butte does not mark a period of major regional disconformity during middle Callovian time.

West of the Black Hills the Member is a bit more variable in composition. Gypsum is present at Alcova (pl. 20) and gypsum stringers are common at Douglas.

To the south at Freezeout Mountains (pl. 15 and 20) the Lak Member loses its characteristic red color and is replaced by sandstone, the lower portion of which is soft (pl. 5, fig. 2) and the top portion of which is ledge-forming (pl. 5, fig. 1), cross-bedded, and contains iron nodules.

Farther west, in the Lander area, the Lak Member is typically red and maroon. It pinches out between Lander and Maverick Spring (pl. 20). It is not present in northern Wyoming (pl. 21).

Imlay (1947) suggested that its absence in northern Wyoming is due to either erosion of the red beds during post-Lak time or to deposition in that area of normal marine shale while the Lak redbeds were formed in the southern and eastern margin of the sea. Imlay favored the first interpretation (although he did not eliminate the possibility of the second), because he believed erosion occurred between Rierdon and Swift time in the areas of the Sweetgrass Arch and the Little Belt Mountains of Montana.

The second interpretation seems more reasonable. Firstly, there is no definite physical evidence (e.g., weathered surfaces, truncation, channeling) of a disconformity between the "Lower" and "Upper Sundance" in northern Wyoming. Even if a disconformity exists (pg. 14, Quenstedtoceras collieri and Kepplerites mclearni) it does not necessarily follow that the Lak was deposited in northern Wyoming and later removed by erosion.

Secondly, as discussed on pages 65 - 73 , south-central and eastern Wyoming and the Black Hills during the early and middle Callovian was an area of lagoons, partially or completely cut off from northern Wyoming by shoals (Sheridan Arch of Peterson, 1957). Shallowing of the Wyoming shelf (pg. 72) apparently caused restricted circulation which resulted in hypersalinity (Lak redbeds and gypsum)

southeast of the arch. It therefore seems to me that the present geographic distribution of the Lak represents temporal environmental response rather than post-depositional erosion in northern Wyoming.

Pine Butte Member.-- The Pine Butte Member is used as defined by Pipiringos (1968) for light greenish-white ledge-forming sandstone, often interbedded with siltstone and olive-gray shale. It occurs stratigraphically between the Lak Member and Redwater Shale. Its geographic distribution includes the Black Hills and south-central and eastern Wyoming as far west as Sheep Mountain (Pipiringos, 1968)(pl. 20).

The Pine Butte Member contains a variety of sedimentary features. Some of the sandstone beds are extensively cross-bedded (Douglas and Freezeout Mountains, pl. 6, fig. 1), extremely oolitic (Freezeout Mountains, pl. 15), burrowed (Douglas), symmetrically ripple-marked and contain centrally furrowed trails (Freezeout Mountains and Alcova, pl. 15, 14 respectively), and contain broken oyster shells and crinoid columnals (Freezeout Mountains, pl. 15). At Douglas a sandy biosparite bed near the top of the member contains Camptonectes bellistriatus shell fragments.

At these localities the Pine Butte Member is in sharp contact with the underlying Lak Member and the overlying Redwater Shale.

Pipiringos (1968) suggests that the Redwater Shale truncates the Pine Butte in south-central and eastern Wyoming and accordingly indicated a disconformity between the two. Plate 20 shows the Pine Butte's geographic restriction to southeastern Wyoming. The lateral thinning and pinching out at the Pine Butte may reflect its original areal extent of deposition rather than due to post-depositional erosion.

The sedimentary features and areal extent of the Pine Butte Member (discussed above) indicate that it is a marginal marine deposit that formed along the southern and eastern margin of the sea as the Wyoming shelf subsided in Late Callovian time after deposition of the Lak beds. The Pine Butte may in part be a facies of the Redwater Shale (pl. 20).

Redwater Shale Member. -- The Redwater Shale Member is used as defined by Pipiringos (1968) for a sequence of clayey siltstone, clay shale, and beds of fossiliferous sandstone or limestone. It is widely distributed throughout the Black Hills and south-central Wyoming (pl. 20). In central and eastern Wyoming it varies very little in lithology and is predominantly shale and siltstone containing belemnites. Further west at Bull Lake and Maverick Springs the upper part of the member is glauconitic sandstone (pl. 6, fig. 2; pl. 16; pl. 20). The shale containing belemnites is still present at these localities (below the glauconitic sandstone) but it is much thinner than in central and eastern Wyoming and the Black Hills.

The Redwater Shale conformably overlies the Hulett, Lak, or Pine Butte Members and is overlain by either the Windy Hill Sandstone Member of the Sundance Formation or the Morrison Formation.

The Redwater Shale in the Black Hills and eastern Wyoming, although predominantly shale and siltstone, does contain a variety of fossiliferous sandstone and limestone beds that occur mainly in the middle and upper part of the member.

At Newcastle (pl. 13) several sandstone beds are full of oyster and other bivalve shell fragments (pl. 8, fig. 1). Further south, at Freezeout Mountains (pl. 15) are several thin beds of oyster-shell coquina. The bottom of the member here also contains sandstone that is trail-marked and symmetrically rippled. At Douglas the top of the section is crossbedded, ripple-marked sandy biosparite packed with bivalve shell fragments (pl. 6, fig. 3).

At Alcova (pl. 14) the upper 20 feet of the member contains limestone ledges full of Camptonectes bellistriatus valves (pl. 6, fig. 4; pl. 7, fig. 2), the latter tightly packed together and welded by calcite cement or irregularly scattered in lime mud (pl. 8, figs. 2, 3). These ledges are interbedded with slabby silty sandstone which contains shell fragments of oysters, Camptonectes, and belemnites. At both Alcova and Douglas there are clam-bored limestone cobbles covered with

oyster spats near the top of the member. These cobbles were not found at any other locality.

Farther west, at Vinceants Ranch and Lander bivalve shells are usually tightly packed together in all the limestone ledges (pl. 7, fig. 3) and may contain other sedimentary grains such as oolites, pellets, and intraclasts. The grains are cemented together by calcite or lime mud or microcrystalline limestone (pl. 8, fig. 4). The limestone is interbedded with platy, ripple-marked, cross-bedded, burrowed sandstone and some greenish-gray sandy siltstone.

Although the contact between the Redwater Shale and Windy Hill Sandstone is sharp, it appears to be conformable. The sequence of lithologic changes at Alcova (pl. 14) from shale containing sandstone stringers and clam bored limestone cobbles to silty sandstone to several limestone benches in the upper 20 feet of the Redwater Shale to oolitic rippled sandstone of the Windy Hill Sandstone suggests continued shallowing as does the sequence at Seminoe Dam (pl. 20). Here, cross-bedded sandstone and oolitic, ripple-marked limestone at the top of the Redwater Shale is overlain by oolitic, festoon cross-bedded sandstone of the Windy Hill Sandstone.

At Bull Lake and Maverick Springs (pl. 16), the member includes a proportionately greater amount of sandstone in its middle and upper parts. This sandstone is designated as the upper sandstone unit of the Redwater Shale. This sandstone is glauconitic throughout, contains belemnite shells in its lower part, contains Camptonectes bellistriatus beds, and is frequently cross-bedded and ripple-marked. The sandstone represents the influence of a clastic source area to the west which also served as a source for the Preuss and Stump Sandstones. This upper cliff-forming sandstone is overlain by variegated shale of the Morrison Formation at Bull Lake and by 40 feet of grayish-white sandstone that may be the Windy Hill Sandstone at Maverick Springs (pl. 16).

Windy Hill Sandstone Member.-- The Windy Hill Sandstone is used as defined by Pipiringos (1968). It is a ledge-forming limy,

oolitic, sparsely fossiliferous sandstone which varies considerably in color from gray-white to brownish-gray and shades of yellowish-brown.

It is geographically distributed throughout south-central and eastern Wyoming, occurring between the underlying Redwater Shale and overlying Morrison Formation (pl. 20).

The type locality for the Windy Hill Sandstone is at the Freezeout Mountains (pl. 15) (Pipiringos, 1968) where the member consists of 12 feet of ledge-forming sandstone (pl. 12, fig. 3) that is symmetrically rippled and contains pebbles in its lower part.

Elsewhere, the Windy Hill Sandstone is oolitic and cross-bedded (pl. 9, fig. 1), and symmetrically ripple-marked (pl. 9, fig. 2). The Windy Hill Sandstone represents deposits formed during Oxfordian regression.

Sundance Formation of Northern Wyoming

"Lower Sundance".-- The "Lower Sundance" is used here as defined by Imlay (1956). The unit contains a lower sandstone member, a middle shale member, and an upper sandstone member (pl. 17).

The lower sandstone member is well exposed at Lovell and Thermopolis (pl. 21). At Thermopolis (pl. 9, fig. 3) the member is sandy oosparite (pl. 11, fig. 1) that is cross-bedded throughout. At Lovell, it is predominantly oolitic claystone interbedded with several oolitic limestone beds. As shown on plate 20 the lower sandstone unit of the "Lower Sundance" is thickest at these two localities. It was not found at Tensleep, probably because the first several feet of the section were grass covered. The stratigraphic position of the lower sandstone member is the same as the Canyon Springs Sandstone in south-central Wyoming. Like the Canyon Springs Sandstone, it represents deepening of water over the Wyoming shelf in early Callovian time.

The medial shale member is well exposed throughout northern Wyoming (pl. 21). It is uniform in composition, predominantly olive-green, soft calcareous shale. As at Lovell, exposed bedding planes

are covered with Gryphaea nebrascensis (pl. 10, fig. 1). It is about 80 feet thick and makes up the entire "Lower Sundance" at Cody (pl. 18). From Lovell it gradually becomes thinner southward to about 16 feet near Hyattville. It pinches out just northwest of Tensleep (Imlay, 1956) and appears again south of Tensleep and at Thermopolis where it is 18 feet thick.

The thinning and pinching out of the medial shale member and the thickening of the sandstone of the upper sandstone member along the eastern and southern sides of the Bighorn Basin apparently reflects the presence of a topographic high in the Thermopolis-Tensleep-Hyattville area during early Callovian time (the Sheridan Arch of Peterson, 1967). The presence of a topographic high across the Wyoming shelf is also demonstrated by the abrupt changes in macrofauna and microfauna to the north and south of the arch (text-figs. 11-13), and the presence of Lak redbeds reflecting restricted circulation south of the arch.

The upper sandstone member is well exposed at all localities except at Cody where a single sandstone ledge occurring near the top of the "Lower Sundance" may represent the westernmost extent of the member as it pinches out from the east.

At Thermopolis (pl. 17) the member is predominantly white or yellowish-tan calcareous fine-grained sandstone interbedded with medium-gray siltstone and gray shale (pl. 9, fig. 4). The sandstone is cross-bedding and interference and oscillation ripple-marked (pl. 10, figs. 2, 3). A sandy oosparite (pl. 11, fig. 2) bed is also present.

At Tensleep the member is quite similar to that at Thermopolis and contains an oobiosparite bed packed with bivalve fragments, pellets and intraclasts. At Lovell, oolites occur in stringers within the sandstone.

This upper sandstone member of the "Lower Sundance" is laterally continuous with the Hulett Sandstone Member as exposed in south-central Wyoming and like the Hulett Sandstone represents shallow water deposits formed during Callovian time.

"Upper Sundance."-- The "Upper Sundance" is used here as defined by Imlay (1956). It contains a lower shale member and an upper sandstone member along the east and south sides of the Big Horn Basin (pl. 21). At Cody, delineation of the lower shale member and upper sandstone member is not possible because sandstone is not restricted to the upper part of the "Upper Sundance" (pl. 18).

The lower shale member is predominantly dark-green, calcareous, belemnite shale. The shale includes interbeds of limestone and sandstone, some of which contain Camptonectes bellistriatus (pl. 5, figs. 3, 4) and other bivalves that are tightly packed together.

At Tensleep, ammonites of the genus Cardioceras were found about 44 feet above the base of the "Upper Sundance." These are the first ammonites ever found in the "Upper Sundance" along the east side of the Bighorn Basin.

The contact of the lower shale member with the "Lower Sundance" is conformable.

The upper sandstone member is thickest at Lovell (117 feet). The member is glauconitic yellowish-brown sandstone that is extensively cross-bedded and symmetrically- and interference-rippled (pl. 17). As at Tensleep and Hyattville, the upper sandstone member contains internal molds of bivalves and bivalve shell fragments.

Eastward, at Cody, the "Upper Sundance" is not divisible into a lower shale member and an upper sandstone member. The lower 90 feet are dominated by glauconitic sandstone that is cross-bedded, contains fossil fragments (pl. 10, fig. 4), and is locally burrowed. The top of the "Upper Sundance" is cross-bedded sandstone.

The upper sandstone member of the "Upper Sundance" represents the last phase of marine sedimentation in Wyoming. The sedimentary features (cross-beds and ripple-marks) indicate shallowing of the water across the Wyoming shelf during early Oxfordian regression. The sands were derived from the west and were deposited along with the Stump Sandstone in western Wyoming.

Twin Creek Limestone

The Twin Creek Limestone was defined by Imlay (1967). He discussed the regional aspects of each member of the formation in terms of regional variations in lithology and paleontology. The two sections discussed here are Cabin Creek and Ditch Creek (pl. 20 and 21).

In general, most members of the Twin Creek Limestone become thicker and more limy from Ditch Creek to Cabin Creek in the offshore direction (text-fig. 9).

Gypsum Spring Member.-- This is the lowest member of the Twin Creek Limestone. At both Ditch Creek and Cabin Creek it is predominantly light-pink, vuggy, brecciated limestone, but at Ditch Creek the top 10 feet of the member is red-brown calcareous shale that grades upwards into the overlying Sliderock Member.

Sliderock Member.-- At Ditch Creek the Sliderock Member contains 15 feet of brownish-gray calcareous silty shale overlain by 30 feet of blocky, medium-gray, oosparite (pl. 11, fig. 4; pl. 19) containing oyster fragments in its upper parts. At Cabin Creek the member is a very dark gray, platy, splintery limestone and does not contain oolites and shell fragments.

Rich Member.--This is the third member of the Twin Creek Limestone and overlies the Sliderock Member. At Ditch Creek it is a fairly homogeneous unit of calcareous shale with an occasional thin bed of black micrite.

At Cabin Creek the member is thicker and the lithology is slightly more varied. The predominant lithology is a medium-gray splintery, shaly limestone with several thin beds of dark-gray, fossiliferous micrite (pl. 12, fig. 2) occurring in the lower 25 feet. The beds of fossiliferous micrite are frequently symmetrically rippled and covered with crinoid columnals indicating current action strong enough to transport skeletal debris.

Boundary Ridge Member.-- This member of the Twin Creek Limestone is predominantly maroon, calcareous, silty shale at both Cabin Creek and Ditch Creek, but at Cabin Creek limestone occurs in the lower part of the member. The limestone beds commonly contain shell fragments, pellets, and intraclasts. Evidence of a soft-bodied bottom fauna is indicated by sand-filled burrows (pl. 12, fig. 4).

Watton Canyon Member.-- This member at Ditch Creek is brownish-gray to gray calcareous siltstone overlain by medium-bedded oolitic limestone. The Watton Canyon Member is thicker at Cabin Creek where the limestone includes oosparite and biomicrite and is occasionally symmetrically ripple-marked.

Leeds Creek Member.-- At Cabin Creek this member consists of about 340 feet of predominantly light-gray splintery shaly limestone. Occurring regularly throughout the member are thin beds of dark-gray micrite and sandy biosparite which is burrowed and packed with shell fragments (pl. 12, fig. 1). The most distinctive bed is an encrinal limestone which occurs near the top of the member.

At Ditch Creek, 128 feet of Leeds Creek Member are exposed. This may not be the true thickness, since the slope is slumped. It may be of the same order of thickness as at Lower Slide Lake where it is 163 feet thick. The member is homogenous throughout and consists of medium-gray calcareous shale.

Giraffe Creek Member.-- The top member of the Twin Creek Limestone is the Giraffe Creek Member. It occurs at Cabin Creek but not at Ditch Creek. About 35 feet were measured at Cabin Creek where it is very silty, slabby limestone which is overlain by light greenish-gray and salmon-colored, very platy, symmetrically rippled, calcareous siltstone of the Preuss Sandstone.

Preuss and Stump Sandstones

The overlying Preuss and Stump Sandstones are western deposits time equivalent to the upper part of the Sundance Formation. They

represent a variety of prodelta or tidal flat deposits (Preuss Sandstone) and shallow marine sand banks and bars (Stump Sandstone) (Mary Hileman, Masters Thesis). Some of the beds are packed with shell fragments and are very calcareous.

BIVALVE PALEOAUTECOLOGY

Introduction.-- The occurrence, abundance, and life mode of the bivalve taxa is discussed here. Life position reconstructions are based on comparison of the fossil with a taxonomically related recent bivalve, functional aspects of shell shape, and field observations on burial position.

Bivalve natural associations and paleobiogeography are discussed in the next text section on Jurassic Paleoenvironments.

Thirty-two genera and 38 species of bivalves were collected from the Twin Creek Limestone, Gypsum Spring Formation, and Sundance Formation (text-fig. 5). Appendix D lists the collecting localities for each bivalve taxon. The bivalves exhibit a wide variety of life modes resulting from Mesozoic diversification of Paleozoic bivalves that were for the most part epifaunal forms. The Mesozoic radiation was a consequence of mantle fusion and the development of siphons, which enabled the bivalves to invade a greater variety of habitats (Stanley, 1968).

The bivalves represent five feeding groups: infaunal siphon feeders; labial palp deposit feeders; infaunal non-siphonate suspension feeders; infaunal mucus tube feeders; and epifaunal suspension feeders.

In text-figure 5, bivalves are listed in their respective superfamilies inasmuch as bivalve workers generally agree that the superfamilies represent natural groupings of related taxa. The superfamilies recognized in this paper are those from the Treatise of Invertebrate Paleontology, Part N.

Labial palp deposit feeders.-- Nucula sp. is the sole representative of this group. Specimens are abundant but not widely distributed as they were found only at Newcastle in the Stockade Beaver Shale and at Freezeout Mountains in the Redwater Shale. They were collected from shale deposits at both localities indicating that Nucula sp. preferred a mud substrate. All the specimens were on the surface of limy shale

Text-Fig. 5.- Numbers of specimens collected given in right column. f = shell fragments, Bp = molds on bedding planes, m = molds, bf = ledge forming, c = coquina beds.

References for biology of superfamilies: Nuculacea (Drew, 1901; Yonge, 1939, Driscoll, 1964), Arcacea (Yonge, 1953, 1955), Mytilacea (Field, 1922; Newell, 1942; Yonge, 1955), Pinnacea (Yonge, 1953; Rosewater, 1961), Pteriacea (Yonge, 1953a & b), Pectinacea (Herdman, 1903; Daxin, 1928; Yonge, 1936, 1953; Waller, 1969; Kauffman, 1969), Limacea (Studnitz, 1931; Lebour, 1937; Yonge, 1953), Ostreacea (Yonge, 1960; Galtsoff, 1964; Rudwick, 1964; Kauffman, 1969), Trigoniacea (McAlester, 1965; Gould, 1968, 1969), Lucinacea (Allen, 1953, 1958; Kauffman, 1967), Crassatellacea (Saleuddin, 1965), Tellinacea (Yonge, 1949; Holme, 1961), Arcticacea (Forbes & Hanley, 1853; Saleuddin, 1964), Myacea (Yonge, 1946), Pholadomyacea (Runnegar, 1966), Pandoracea (Allen & Allen, 1955; Yonge, 1937, 1952).

Superfamily	Species	Substrate Preference	Abundance	Feeding Type
Nuculacea	Nucula sp.	mud	72	Labial palp deposit feeder
Arcacea	Grammatodon haguei	mud	4	Infaunal nonsiphonate suspension feeders
	Idonearca haguei	mud	1	
	Idonearca sp.	silty sand	1,m	
Pinnacea	Pinna kingi	mud	2	
Trigoniacea	Vaugonia conradi	silt or sand	29	
	V. sturgisensis	sand	7,m	
	Trigonia sp.	silt	1,m	
	T. americana	mud	2,Bp	
	Myopherella sp.	mud	4	
	M. montanaensis	mud	16	
Mytilacea	Modiolus formosus	sand	1	Byssiferous epifaunal suspension feeders
	M. subimbricatus	mud or silt	50,c	
	Modiolus sp.	mud to sand	1,m	
	Mytilus sp.	mud	3	
	M. whitei	sand or shell	20,f	
Pteriacea	Gervillia montanaensis	mud	19	
	Isognoman perplana	mud	1	
Limacea	Lima sp.	mud	2	
	L. occidentalis	mud	3,f	
Pectinacea	Meleagrinella curta	mud to sand	1,387;Bp	Byssiferous or cemented epifaunal suspension feeders
	Camptonectes stygius	mud	78,f	
	C. platessiformis	mud	51,f	
	C. bellistriatus	sand, silt, or shell	87,bf	
	Plicatula sp.	mud	12	
Ostreacea	Gryphaea nebrascensis	mud	3,382;f	Epifaunal suspension feeders
	G. planoconvexa	mud	68	
	Ostrea strigilecula	mud to sand	148,f	
	O. engelmanni	mud	2,f	
	Alectryonia procumbens	mud	400	

Text-fig.5 Bivalve feeding types and substrate preference (continued).

Superfamily	Species	Substrate Preference	Abundance	Feeding Type
Lucinacea	Mactromya sp.	mud	2	Infaunal tube feeder
Crassatellacea	Astarte sp.	mud	2	Infaunal nonsiphonate suspension feeders
	A. packardi	mud or silt	13, Bp	
	A. meeki	mud	41	
	Prorokia fontenellensis	mud	3	
Tellinacea	Quenstedtia sp.	sand	11, Bp	Infaunal siphonate suspension or deposit feeders
	Q. sublevis	mud	5	
	Tancredia sp.	sand	36, Bp	
	T. transversa	sand	18, Bp	
	T. warrenana	sand	Bp	
Arcticacea	Pronoella sp.	mud	41	
	P. cinnabarensis	mud or silt	40, bf	
Myacea	Corbula sp.	mud	4	
	C. munda	mud	Bp	
Pholadomyacea	Pholadomya sp.	sand	1	Infaunal siphonate suspension feeders
	P. kingi	mud	14	
	Pleuromya sp.	mud to sand	16	
	P. subcompressa	mud	135	
	P. newtoni	silt or sand	21	
	Homomya gallatinensis	mud	2	
	Myopholas hardyi	mud	1	
Pandoracea	Platymyoidea sp.	sand	2	
	P. rockymontana	mud	2	
	Cercomya punctata	mud	1	
	Thracia weedi	mud	6	

Text-fig.5 continued.

nodules and not in living position.

Recent species of Nucula are very shallow depth slow-burrowing non-siphonate infaunal bivalves that remain relatively stationary once buried. Food is gathered directly from the sediment by labial palps since the animals do not have incurrent or excurrent siphons (Yonge, 1939; Drew, 1901). Jurassic Nucula (text-fig. 6) probably had a similar life mode and were vertically positioned in the substrate which is common with protobranchs (Driscoll, 1964).

Epifaunal suspension feeders.-- The Mytilacea, Pteriacea, Pectinacea, Limacea, and Ostreacea make up the dominant feeding type in the Middle and Upper Jurassic of Wyoming.

The Mytilacea includes the mytilids and modiolids. The most common forms are Modiolus subimbricatus and Mytilus whitei. A few isolated fragments and whole shells belonging to those genera occur at Lander, Alcova, and Maverick Springs, but are not common.

M. subimbricatus is common to the Twin Creek Limestone, the Gypsum Spring Formation, the "Lower Sundance," and Stockade Beaver Shale. M. whitei is more restricted in its range as it occurs just in the Gypsum Spring Formation and "Lower Sundance" in northern Wyoming.

M. subimbricatus characteristically occur in small local populations made up of tightly packed individual shells. Their occurrence in oolitic claystone in the lower sandstone member of the "Lower Sundance" at Lovell is an excellent example of a well-preserved, relatively undisturbed local population.

M. whitei was also gregarious. At Thermopolis, a small population occurs in an oolitic sandstone in the "Lower Sundance." At Cody their shells make up an entire thin bed within a matrix of calcareous sand of the Gypsum Spring Formation.

These animals (text-fig. 6) were epifaunal suspension feeders that were closely attached to the substrate and held firm by a byssus. The

occurrence of M. subimbricatus and M. whitei in oolitic deposits indicates that they inhabited turbulent water conditions.

Gervillia montanaensis and Isognoman perplana represent the Pteriacea. One specimen of I. perplana was collected in the Rich Member at Ditch Creek. Recent Isognoman are firmly attached to the substrate by a byssus. The flat anterodorsal border of I. perplana (text-fig. 6) suggests that it was permanently attached by means of a byssus.

G. montanaensis is common in limestone of the Rich Member at Lower Slide Lake, where it occurs in pods made up of several individuals. Generally, recent Gervillia are free-swinging bivalves, attached to hard substrates or vegetation by means of a strong byssus (Kauffman, 1969). G. montanaensis may have been attached to vegetation on the sea floor or it may have occurred in local pods made up of several individuals (text-fig. 6), as in the case of pearl oysters. Several shells together may have added support on a soft mud substrate.

The Pectinacea are represented by Meleagrinella curta, Camptonectes stygius, C. bellistriatus, C. platessiformis, and Plicatula sp. The first three were dominant forms in their own respective niches (text-figs. 11, 10 and 14 respectively).

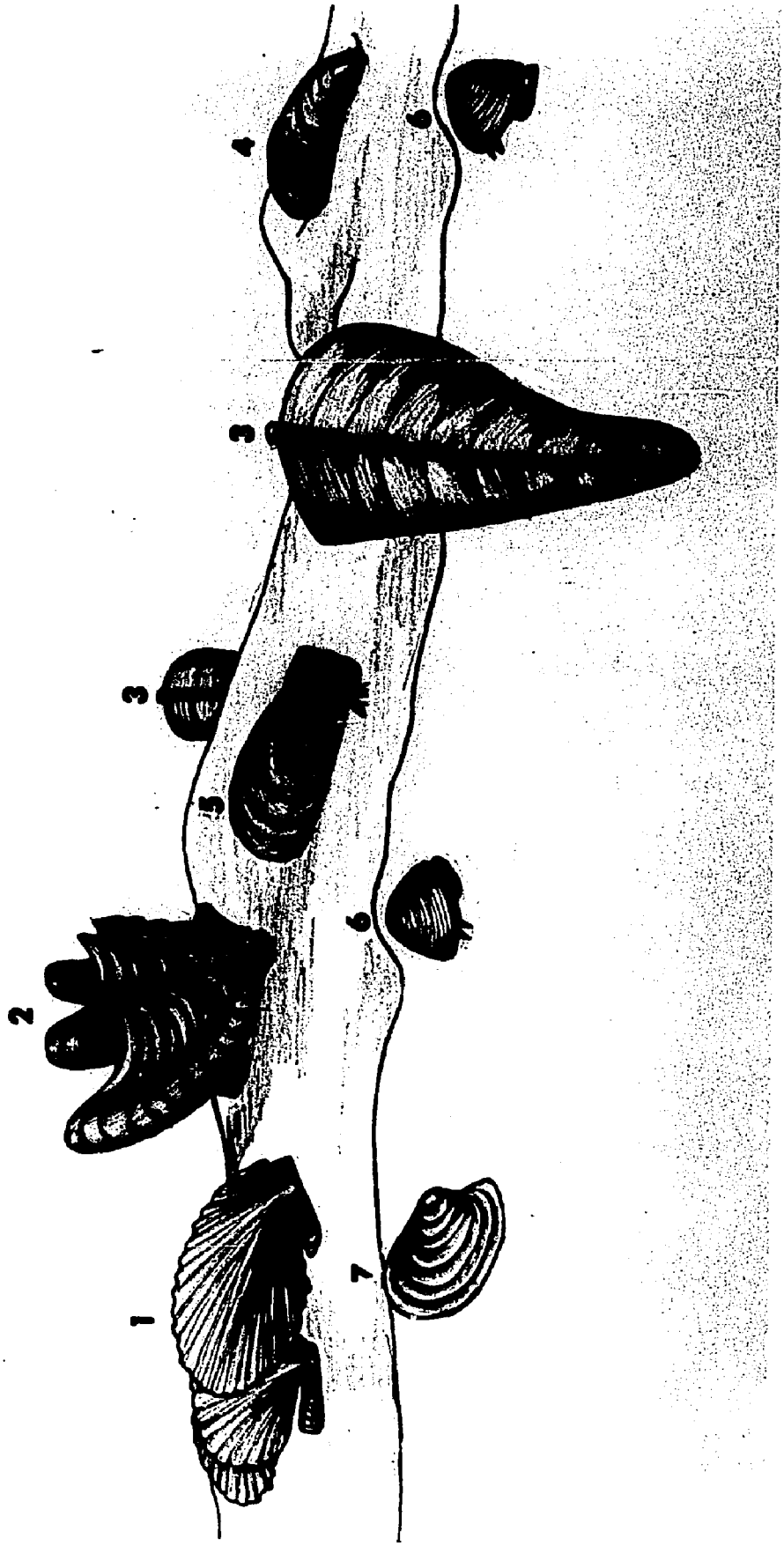
Meleagrinella curta is the second most abundant bivalve collected. It can be found throughout the Sundance Formation but it is most abundant in the Stockade Beaver Shale in south-central and eastern Wyoming (text-fig. 11). It occurs flat-lying predominantly in shale deposits but is commonly found on siltstone or sandstone bedding planes. It was an epifaunal suspension feeder that may or may not have been weakly attached to the substrate by a byssus (text-fig. 8). A deep, right auricular sulcus truncates the anterior dorsal margin of the right valve although the byssal opening remains small.

Camptonectes were also flat-lying epifaunal suspension feeders (text-fig. 6). They were byssally attached by the right valve as indicated by the presence of a deep byssal notch in the right auricle.

The dominant species in western Wyoming was C. stygius which

Text-Fig. 6.- Bivalve life mode reconstructions.

1. Camptonectes stygius (epifaunal suspension feeder)
2. Gervillia montanaensis (epifaunal suspension feeder)
3. Pinna kingi (semi-infaunal nonsiphonate suspension feeder)
4. Modiolus subimbricatus (epifaunal suspension feeder)
5. Isognoman perplana (epifaunal suspension feeder)
6. Nucula sp. (labial palp deposit feeder)
7. Grammatodon haguei (infaunal nonsiphonate suspension feeder)


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is abundant in limestone and limy shale of the Rich, Watton Canyon, and Leeds Creek Members at Cabin Creek. Its slightly convex, subcircular valves were well suited to lying on a soft mud bottom. This disk-shape prevented the animal from nestling too far down into the substrate and becoming passively buried.

C. platessiformis is common in the Twin Creek Limestone and Stockade Beaver Shale but never was a dominant form.

C. bellistriatus occurs throughout northern, central, and eastern Wyoming and is the dominant bivalve in the Redwater Shale and "Upper Sundance." Unlike C. stygius and C. platessiformis, it was gregarious and apparently preferred a sand or shell substrate. A shell substrate provided a hard surface for byssal attachment and a settling place for spat. In addition, it served to elevate the entire shell above the underlying silt or mud bottom. C. stygius or C. platessiformis which occurred on a mud substrate might have solved the problem of silting-in by maintaining a strong byssal attachment which would have elevated the posterior commissural border above the substrate, as in the case of some species of Pinctata (Herdman, 1903).

If the depth of the byssal notch is an indication of the strength of shell attachment, then C. bellistriatus was strongly anchored by its byssus. The animal commonly makes up complete beds in which the valves are tightly packed one on top of another. Occasionally, one can find a few valves that are vertically oriented, but this probably was the result of the valves opening after the animal died.

Plicatula sp. is represented by 12 specimens collected from the Rich Member at Cabin Creek. It lay horizontally disposed on the mud surface, either weakly cemented by the umbo of the left valve or free. The radial corrugations and spines (indicated by the presence of pits used for spine attachment) raised the commissure slightly above the substrate.

The Limacea are represented by a few unidentifiable fragments of Lima sp. collected in the Stockade Beaver Shale at Newcastle. Several

specimens of L. occidentalis were collected in the Rich Member at Ditch Creek and Lower Slide Lake. Recent Lima species are both swimmers and byssally attached nestlers. The subovate to oblique outline of L. occidentalis plus the presence of a long lunule resulting in a flat anterodorsal border suggests that it was permanently attached by means of a byssus (text-fig. 7). Although all Recent examples of Lima that are byssally attached have their valves vertically disposed to the substrate (Studnitz, 1931), Yonge (1953) indicates that it is the only monomyarian to do so.

Members of the superfamily Ostreacea comprise the greatest number of epifaunal suspension feeders in the marine Jurassic deposits of Wyoming. Gryphaea nebrascensis is the most abundant bivalve with well over 3,000 specimens collected by me in surface and channel samples. It is the dominant bivalve in the "Lower Sundance" of northern Wyoming, the Stockade Beaver Shale at Maverick Spring and Bull Lake, and the Leeds Creek Member of the Twin Creek Limestone of western Wyoming. East of Maverick Spring it was found only at Newcastle.

Very young individuals of G. nebrascensis were cemented by the umbo of the left valve, as attested by the presence of a large flat attachment scar. They soon became free-living and during growth the animal tilted toward the "ventral" margin and the commissure was reoriented relative to the substrate. They lay sessile and embedded within the mud substrate (text-fig. 7). The deep convexity of the left valve, along with the upward growth of the ventral margin insured that the commissure remained above the substrate. The posterior sulcus added stability to the shell on a mud substrate.

The life mode of G. planoconvexa was the same as G. nebrascensis. Although the shell is subcircular in outline and the left valve is only moderately convex, the flatness of it served the same purpose of keeping the shell from passively settling too far down into the substrate as did the convexity of G. nebrascensis. G. planoconvexa is common only in the Rich Member of the Twin Creek Limestone in western Wyoming.

Alectryonia procumbens was found only at Maverick Spring, where a local population occurs at the base of the Redwater Shale. Each animal was cemented by the umbo of the left valve to the shell of another individual (text-fig. 7). The most outstanding feature of the shell is the strong corrugations which may have served the following purposes: to increase the surface area of the mantle and thereby add to the surface available for respiration; to stabilize the shell on the substrate; to set up eddy currents between the valves, thereby increasing the amount of water passing over the ctenidia per unit time; to elevate the commissure above the substrate; and to strengthen the shell.

The largest oysters in the marine Jurassic of Wyoming are Ostrea engelmanni, which are commonly over three inches in diameter. They were flat-lying (text-fig. 7) and apparently required a hard substrate for attachment because in the "Upper Sundance" at Thermopolis they were cemented by the left valve to valves of Camptonectes bellistriatus. At Lovell and Tensleep fragments of O. engelmanni were found within a 10- to 15-foot interval in the "Upper Sundance." The producing bed was not located because of talus cover, but the concentration indicates that the shells must have weathered from locally developed oyster banks.

O. strigilecula is fairly abundant and occurs at almost every locality. Although occurring in limestone and shale at Cabin Creek, Ditch Creek, and Lower Slide Lake, the oyster is more common in sandstone beds of the Sundance Formation. These sands (i.e., Canyon Spring Sandstone, Pine Butte Member, etc.) are deposits formed in high energy environments. O. strigilecula was capable of surviving in a high-energy environment because it was attached by a large attachment scar on the left valve.

Infaunal nonsiphonate suspension feeders.-- This group is represented by the Pinnacea, Arcacea, Trigonacea, and Crassatellacea. The first two are minor elements of the Jurassic bivalve fauna and total just six specimens.

Two incomplete specimens of Pinna kingi were collected, one from the Rich Member at Ditch Creek and the other from the same member at Lower Slide Lake. The latter specimen was found in living position (text-fig. 6).

Recent Pinna is more correctly called a semi-infaunal suspension feeder because part of the posterior end of the shell projects above the substrate. The bivalve is sessile and may anchor itself to a shell fragment within the substrate by a byssus. Although the posterior part of the shell projects above the substrate, it is not prone to predation because the mantle which lines the inner surface of the valves can be completely withdrawn from the posterior end of the shell to the anterior (Yonge, 1953).

Members of the superfamily Arcacea are rare. Only one specimen of Idonearca haguei was found at Ditch Creek in the Rich Member of the Twin Creek Limestone. Grammatodon haguei was collected at Ditch Creek, Douglas, Maverick Spring, and Tensleep.

Many genera of the superfamily Arcacea (i.e., Arca) are epifaunal nestlers and byssally attached to the substrate (Yonge, 1953a, 1955). They characteristically possess a shallow, mid-ventral, concave reentrant marking the position of the large byssal gap. The shells are generally subquadrate and elongate. The shells of Grammatodon haguei and Idonearca haguei are more ovate, have closed margins along the entire commissure, and have a slightly convex venter indicating the absence of a byssal reentrant. They were therefore not epifaunal nestlers but probably had a life mode like Anadara, which has a similar shape. They are interpreted to having been infaunal nonsiphonate suspension feeders (text-fig. 6).

A similar life mode is present in the Trigonacea. The family Trigonidae consists of genera that are active free-living bivalves, equipped with a large muscular foot enabling them to burrow rapidly (Gould, 1968). They are infaunal nonsiphonate suspension feeders with the posterior margin of the shell at the sediment water interface (McAlester, 1965) (text-fig. 7).

Members of the Trigonacea are fairly common. Vaugonia conradi is the most common with 29 specimens being found. Although only three specimens were found in the Rich Member at Ditch Creek and Lower Slide Lake, specimens are more common in siltstone and sandstone beds of the Canyon Springs Sandstone, Stockade Beaver Shale, and "Lower Sundance."

V. sturgisensis is common in sandstone deposits within the Redwater Shale or "Upper Sundance."

Trigonia americana and Myophorella montanaensis, found in shale and limestone beds, evidently preferred a mud substrate. T. americana is the dominant bivalve in the Gypsum Spring Formation at Cody, Wyoming.

The Crassatellacea are represented by Astarte meeki, A. packardi, Prorokia fontenellensis, and two poorly preserved specimens of Astarte sp. P. fontenellensis is rare; one specimen was collected in the Gypsum Spring Formation at Cody, and two in the Rich Member at Cabin Creek. A. meeki, the most abundant of all three species, occurs along with P. fontenellensis in the Gypsum Spring Formation at Cody. It also occurs throughout the Twin Creek Limestone (except in the Gypsum Spring and Giraffe Creek Members), although it is common only in the Rich Member. A. packardi is characteristic of upper Jurassic Sundance deposits, but it is not common.

The Astartes were nonsiphonate suspension feeders (text-fig. 7). In recent Astarte the exhalant siphon extends about 2 mm out of the shell while the mantle margin of the inhalant aperture is flush with the shell margin. They are shallow burrowers with the posterior shell margin flush with the sediment-water interface (Salenddin, 1965).

Infaunal tube feeders. -- The one representative of this group is Mactromya? sp. It is rare; only two specimens were found, one from the Rich Member at Lower Slide Lake and the other from the lower part of the Stockade Beaver Shale at Maverick Springs. If the specimens are correctly identified as Mactromya, then their life mode was similar to

other members of the Lucinacea (text-fig. 7). It would have been equipped with a vermiform mucus-secreting foot which would construct the anterior inhalant respiratory and feeding tube (Allen, 1953, 1958; Kauffman, 1967).

Infaunal siphonate suspension feeders.--This feeding group includes the Tellinacea, Arcticacea, Myacea, Pholadomyacea, and Pandoracea.

The Tellinacea are represented by Quenstedtia sublevis, Tancredia transversa, T. warrenana, and many very small internal molds assigned to Quenstedtia sp. and Tancredia sp. All of the above, except Q. sublevis, were sand bottom dwellers, and all of them, except Q. sublevis, are restricted to the Sundance Formation. Q. sublevis was found only in the Stockade Beaver Shale at Newcastle. Quenstedtia sp., a characteristic bivalve of eastern Wyoming and the Black Hills, commonly covers the surface of sandstone bedding planes of the Hulett Sandstone at Alcova and Buffalo Gap, and the Stockade Beaver Shale at Rapid City.

Tancredia sp. is also common on sandstone bedding planes and occurs in the "Upper Sundance" in northern Wyoming, and in most members of the Sundance Formation in south-central and eastern Wyoming and the Black Hills.

Tancredia transversa is easily recognized and particularly characteristic of sandstone deposits of the Redwater Shale and "Upper Sundance."

T. warrenana was collected at Buffalo Gap, Douglas, and Hyattville, in sandstone of the Canyon Springs Sandstone, Hulett Sandstone, and "Upper Sundance" respectively.

The Tellinacea, including Quenstedtia and Tancredia, are infaunal siphonate suspension or deposit feeders equipped with separate siphons, of which the inhalant siphon is the longer of the two and capable of sweeping the substrate for food (Yonge, 1949). They densely populate marginal marine and littoral environments. Jurassic Tancredia and

Quenstedtia are also found crowded on bedding planes in sandstone deposited in shallow marginal marine and littoral environments.

The Tellinacea may lie horizontally on one valve within the substrate or vertically within the substrate. Tancredia and Quenstedtia are reconstructed in a vertical position (text-fig. 7) because both lack a posterior lateral flexure which is common in bivalves which lie on one valve. The sandstone bedding planes densely covered with molds of these genera may represent wave or storm-deposited shells rather than in situ populations of horizontally disposed individuals. Storm wave action is able to churn up the upper few inches of littoral sand and dislodge the shallow burrowing bivalve infauna.

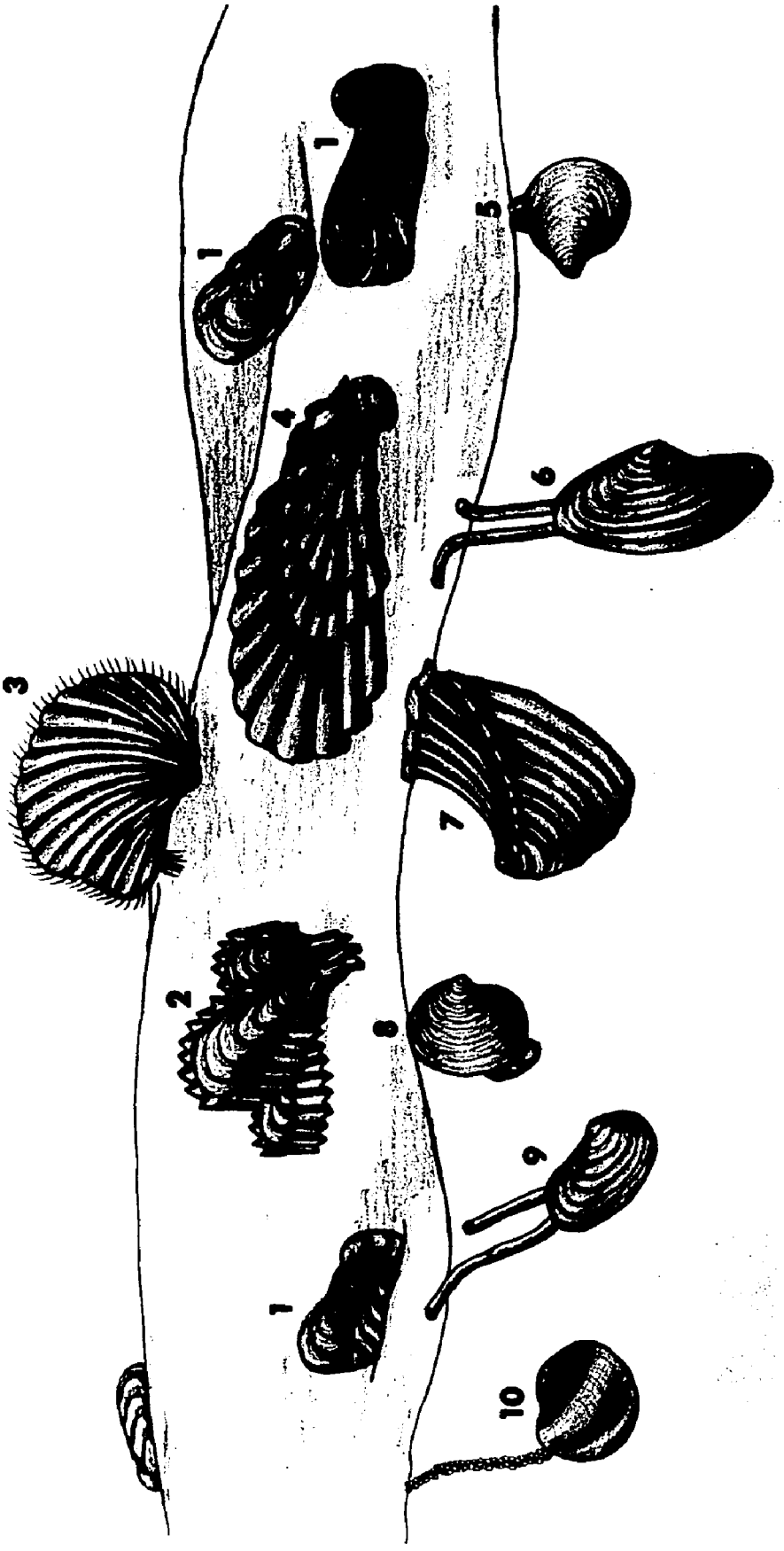
Pronoella cinnabarensis and Pronoella sp. represent the Arcticacea. P. cinnabarensis is represented by one specimen from the Rich Member at Ditch Creek, nine specimens from the Gypsum Spring Formation at Cody, and well over 300 specimens from the lower part of the Stockade Beaver Shale at Maverick Springs, where it is the dominant form. Pronella sp. occurs in abundance within the Rich Member at Lower Slide Lake.

P. cinnabarensis is interpreted to have been a shallow-burrowing siphonate suspension feeder (text-fig. 7). It occurred predominantly in dense populations of turbulent water environments (text-fig. 10). Arctica islandica (a taxonomic cousin with morphologic resemblance to Pronoella sp.) is a shallow burrower with short siphons extending 5 to 8 mm out of the shell (Salenddin, 1964). Siphons are fused and the animal lives in a vertical position. The shell morphology of both Pronoella cinnabarensis and Arctica islandica is very similar, no doubt reflecting similarity in life habits.

Specimens of Corbula munda are not very abundant. It was collected from the Rich Member at Ditch Creek and Cabin Creek. Corbula sp. occurs in the Rich Member at Ditch Creek and Lower Slide Lake and in the Gypsum Spring Formation at Cody. Although Corbula munda is inequivalved, it was not found in a horizontal position. It was

Text-Fig. 7.- Bivalve life mode reconstructions.

1. Gryphaea nebrascensis (epifaunal suspension feeder)
2. Alectryonia procumbens (epifaunal suspension feeder)
3. Lima occidentalis (epifaunal suspension feeder)
4. Ostrea engelmanni (epifaunal suspension feeder)
5. Pronoella cinnabarensis (infaunal siphonate suspension feeder)
6. Tancredia warrenana (infaunal siphonate deposit feeder)
7. Trigonia americana (infaunal nonsiphonate suspension feeder)
8. Astarte meeki (infaunal nonsiphonate suspension feeder)
9. Quenstedtia sublevis (infaunal siphonate deposit feeder)
10. Mactromya sp. (infaunal tube feeder)


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a shallow-burrowing infaunal siphonate suspension feeder with the posterior shell margin close to the substrate surface (text-fig. 8). Recent Corbula are byssally attached. The robust shell adds further resistance and aids in maintaining a stationary position.

The Pholadomyacea are represented by Myopholas hardyi, Homomya gallatinensis, Pleuromya subcompressa, P. newtoni, Pleuromya sp., Pholadomya sp., and P. kingi. H. gallatinensis and M. hardyi are rare. Two specimens of the former were collected from the Rich Member at Lower Slide Lake and one of the latter occurred in the Leeds Creek Member at Ditch Creek.

Pleuromya subcompressa is the most abundant bivalve of this group, the dominant bivalve in the Rich Member at Ditch Creek and Lower Slide Lake. It was a mud dweller. P. newtoni, typical of "Upper Sundance" and Redwater Shale deposits, was a sand dweller.

Pholadomya kingi is only common in the Rich Member of the Twin Creek Limestone. P. kingi was an infaunal siphonate suspension feeder (text-fig. 8). The shell is elongate with a flaring posterior siphonal gap indicating the relatively large size of the siphons. The animal was a deep burrower whose only movements may have been the retraction and extension of the siphons, like those in other deep burrowers such as Panope and Mya.

Homomya gallatinensis is similar in shape to Pholadomya kingi and probably had the same life mode.

Pleuromya subcompressa was also a burrower (text-fig. 8). It has a deep pallial sinus and a moderate posterior siphonal gap. It is not as elongate as Pholadomya kingi and may not have burrowed as deeply. The posterior siphonal gap of Myopholas hardyi suggests that it was also a relatively deep burrower.

The Pondoracea are not dominant among the infaunal siphonate feeders in the Sundance Formation or Twin Creek Limestone. Two specimens of Platymyoidea rockymontana were collected from the "Upper Sundance" at Hyattville and are referred to Platymyoidea sp. Cercomya

punctata and Thracia weedi also occur in the Rich Member of the Twin Creek Limestone.

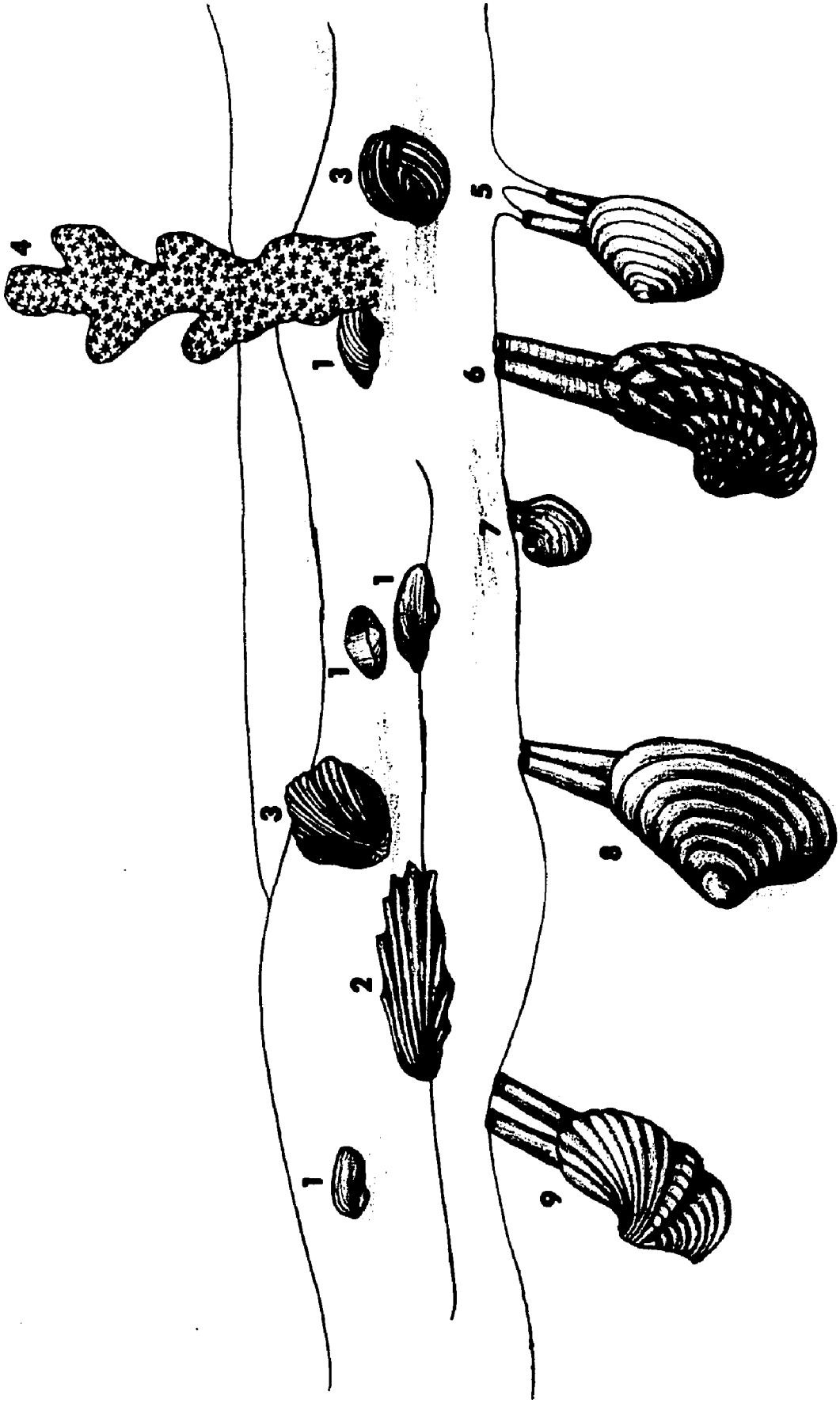
The majority of the Pondoracea are shallow burrowers, possessing short separate siphons which may or may not have built mucus-lined siphonal tubes (Allen & Allen, 1955; Yonge, 1937, 1952). The separation of the siphons was probably not due to the same response as in the Tellinacea, which used the incurrent siphon to actively sweep the bottom sediments, but as a response to building the mucus-lined tubes. The Pondoracea may be vertically or horizontally disposed beneath the substrate.

Yonge (1937) has discussed the mucus-secreting habit of the Recent Thracia pubescens. T. weedi probably had the same life mode. The compressed shell of T. weedi indicates that the animal was streamlined for rapid burrowing in a relatively firm mud substrate and capable of frequently moving about constructing new mucus-lined funnels. Platymyoidea rockymontana and Cercomya punctata are more inflated than T. weedi. This may indicate that they were slower or shallower burrowers or both (text-fig. 8).

The coral Actinastrea hyatti and the rhynchonellid brachiopod Kallirhynchia myrina are included in text-fig. 8 because they made up a dominant part of the epifauna in their respective localities. A. hyatti is abundant in the Gypsum Spring Formation at Cody and K. myrina is common to sandstone deposits within the Redwater Shale Member at Maverick Springs and Bull Lake and the Stump Sandstone farther to the west.

Text-Fig. 8.- Bivalve life mode reconstructions.

1. Meleagrinella curta (epifaunal suspension feeder)
2. Plicatula sp. (epifaunal suspension feeder)
3. Kallirhynchia myrina
4. Actinastrea hyatti
5. Thracia weedi (infaunal siphonate suspension feeder)
6. Pholadomya kingi (infaunal siphonate suspension feeder)
7. Corbula munda (infaunal siphonate suspension feeder)
8. Pleuromya subcompressa (infaunal siphonate suspension feeder)
9. Cercomya punctata (infaunal siphonate suspension feeder)


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JURASSIC PALEOENVIRONMENTS

Introduction

Several paleoecologic "tools" have been used to derive a representative picture of what the marine environments were like in the Wyoming area during Middle and Late Jurassic time.

The spatial and temporal distribution of sedimentary environments and fauna has been determined for Middle and Late Jurassic time (text-figs. 9-15). Stratigraphic data is incorporated with selected rock thin sections which show the abundance and kinds of sedimentary grains and the matrix material. The proportion of micrite to sparite is used as an index to water turbulence (Folk, 1962; Dunham, 1962). The presence of micrite signifies the absence of vigorous currents, whereas sparite fills the pore spaces in the rock where micrite was washed out or not available because of current action.

The usefulness of microfossils in paleoenvironmental studies is well established. Distribution of the major groups of foraminifera (arenaceous, hyaline, porcelaineous) is useful in mapping changes in bathymetry, salinity, and temperature (Bandy, 1956, 1960; Greiner, 1970; Walton, 1964). Greiner (1970) has shown that bathymetry, salinity, and temperature in the Gulf of Mexico determine the availability of $CaCO_3$ which is used in shell construction by the foraminifera. In general, normal saline, shallow, warm water has more available $CaCO_3$ than low saline, deep, cold water.

Arenaceous foraminifera are more abundant than calcareous (hyaline and porcelaneous) foraminifera wherever the $CaCO_3$ content of sea water is low, because calcareous foraminifera utilize $CaCO_3$ for shell secretion. Because arenaceous and calcareous (hyaline) foraminifera are well represented in Jurassic deposits in Wyoming and South Dakota, possible changes in water depth, salinity, and temperature may be determined. Changes in faunal dominance and faunal diversity were also useful. Walton (1964) defined faunal dominance as "the percentage

occurrence of the most common species in a foraminiferal population." In nearshore environments the foraminiferal population characteristically has many individuals of one or a few species. Faunal diversity (the number of species) increases offshore.

The use of ostracods as paleoecologic indicators, along with the ecology of recent forms, has been discussed at length by Puri and others (1964).

Ostracods are more abundant in numbers of individuals in marginal marine environments. The number of species increases away from the shoreline (Swain, 1955). Limited data also suggest that the foraminifera/ostracod ratio is lowest near shore (Bandy, 1964; Upshaw et al., 1966), and that ostracods dominate the microfauna to the exclusion of foraminifera in hypersaline lagoons (Upshaw et al., 1966).

Similar trends in Middle and Upper Jurassic ostracods have been useful in determining possible salinity and bathymetry changes in the Jurassic environments.

Microfossils from samples of 8 strategically located sections (appendix E and pl. 20 & 21) were useful in delineating environments during Callovian and Oxfordian time. Appendix E gives the abundance and location of foraminifera and ostracods from the washed samples.

Natural associations of bivalves proved helpful in defining the general framework of spatial environmental changes. Associations were defined on the basis of their geographic and stratigraphic recurrence and relative abundance. A particular association is named after the dominant one or two taxa (i.e., Camptonectes stygius dominance). Individual taxa, although common to one association, may not be restricted to that one particular association but may occur in others. The use of recurrent species in recognizing associations is in accordance with Peterson's (1914) concept of marine bottom communities, which forms the basis of most bottom marine ecology (Thorson, 1957).

The associations are interpreted to represent portions of once living bottom communities. They are not called "fossil communities"

because a major portion of each community no doubt consisted of plants and animals without preservable hard parts and therefore not represented. Use of the term community is restricted to Recent ecology.

Middle Jurassic

Bajocian sedimentary environments.-- The Jurassic sea spread southward from the Arctic region in early, middle, and late Jurassic times. Transgression extended only as far south as British Columbia in the Early Jurassic (Imlay, 1957) but reached the Wyoming area by the Middle Jurassic.

The sediments deposited during Bajocian time include gypsum and brownish siltstone of the Gypsum Spring Member of the Twin Creek Limestone in western Wyoming and gypsum and redbeds of the Gypsum Spring Formation throughout north-central and eastern Wyoming and the Black Hills region. These sediments indicate that hypersaline conditions were initially very widespread and persisted throughout Wyoming, and South Dakota during Bajocian time. Southeastern Wyoming was not submerged at this time and remained a lowland source area for fine sand and silt. Further transgression or shelf deepening resulted in freshening the marine water. The thick limestone deposits of the Sliderock and Rich Members of the Twin Creek Limestone were formed at this time in western Wyoming.

The base of the Sliderock Member is often marked by a bench-forming oolite bed (Imlay, 1967) denoting turbulent water conditions during the Bajocian. In addition, the water may have remained shallow enough as minor fluctuations in sea level, land elevation, or storms, resulted in the deposition of several thin limestone beds containing aggregates of pellets, intraclasts, and broken shells. Westernmost Wyoming was at this time the site of very rapid accumulation of lime mud which resulted in thick deposits of limestone. The general lack of high energy deposits and sedimentary structures indicates that quiescent, open-shelf conditions prevailed (text-fig. 9).

While lime mud deposition continued at a rapid rate at Cabin

Creek along the Wyoming-Idaho border, farther eastward (Ditch Creek and Lower Slide Lake) the rate of lime mud deposition was not as great and mostly clay mud was being deposited from nearby land source areas. The Sliderock and Rich Members are much thinner here than at Cabin Creek, probably indicating a slower rate of subsidence at Ditch Creek and Lower Slide Lake.

Gypsum and redbeds continued to be deposited in hypersaline lagoons in west-central and northern Wyoming (text-fig. 9). Flushing of the lagoons in the Bighorn basin area by sea water of normal salinity resulted in temporary cessation of evaporite deposition. Normal marine limestone, shale, and claystone of the middle unit of the Gypsum Spring Formation were formed at those times.

In the northern part of the Bighorn basin (e.g., Cody) marine conditions were persistent as the deposits are thick and contain an abundant marine fauna. To the south (Wind River Basin) the hypersaline lagoons were only occasionally flushed by normal marine water and lagoonal, intertidal and supratidal environments persisted (Green, Masters Thesis).

In summary, the regional distribution of depositional environments on the Wyoming shelf during Bajocian time consisted of an open shelf along the Wyoming-Idaho border characterized by rapid subsidence and rapid deposition of lime mud and to a lesser degree, calcareous shale. Along the eastern and northern shoreline were shallow, hypersaline lagoons that contained sediments of gypsum and redbeds. Occasional freshening of the northwestern lagoonal area (i.e., Bighorn Basin) resulted in normal marine deposits there, while hypersaline deposition persisted to the south in the Wind River Basin area.

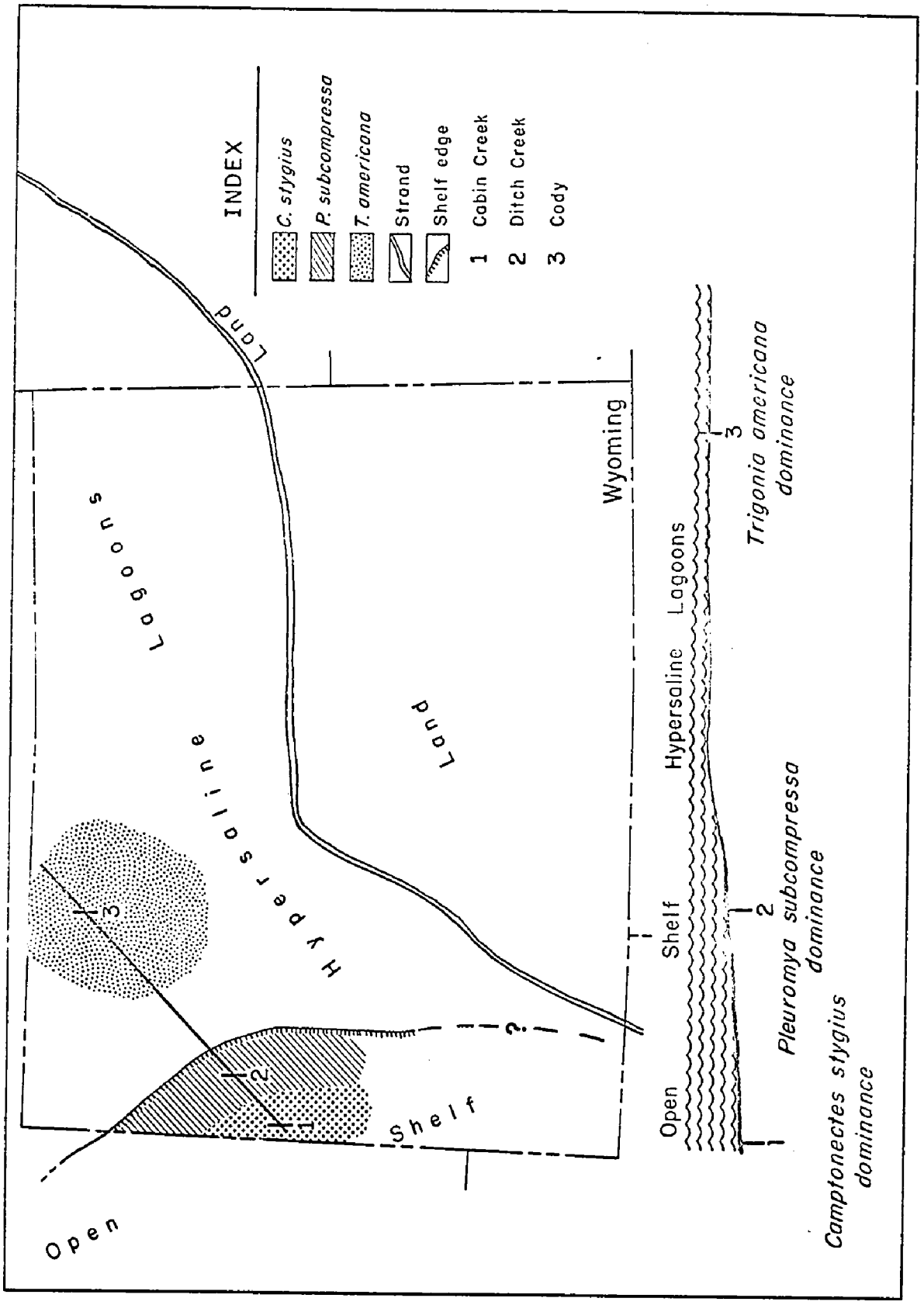
Bajocian bottom fauna.-- In westernmost Wyoming the fauna was neither diverse nor abundant. It included the epifaunal bivalves Camptonectes stygius, Plicatula sp., Ostrea strigilecula, Gryphaea planoconvexa, Camptonectes platessiformis, and the infaunal bivalves Pleuromya subcompressa, Astarte meeki, Thracia weedi, Prorokia

fontenellensis, and Corbula munda.

Camptonectes stygius was the dominant bivalve (text-fig. 9). The region of its occurrence was in an area where lime mud was deposited rapidly. The rapid rate of deposition may have accounted for the low diversity and abundance of the bivalve fauna because it would have hampered food gathering and respiration of most bivalves. The epifaunal bivalves associated with C. stygius were well adapted to a soft mud substrate. They are all flat shelled and would not have passively settled too deeply into the mud.

Farther shoreward (i.e., Ditch Creek) the fauna was much more diverse and abundant. Pleuromya subcompressa was the most dominant bivalve of this zone (text-fig. 9). The bivalve fauna associated with P. subcompressa includes Astarte meeki, Thracia weedi, C. platessiformis, Ostrea strigilecula, Gryphaea planoconvexa, Pleuromya subcompressa, Corbula munda, Isognoman perplana, Trigonia americana, Mactromya? sp., Gervillia montanaensis, Vaugonia conradi, Myophorella sp., Homomya gallatenensis, Cercomya punctata, Pholadomya kingi, Pinna king, Lima occidentalis, Pronoella sp., Modiolus subimbricatus, Platymyoidea rockymontana, Idonearca haguei, Myophorella montanaensis, Grammatodon haguei, Pronoella cinnabarensis, and Mytilus whitei. Pronoella sp., P. kingi, A. meeki, G. montanaensis, C. platessiformis, G. planoconvexa, and O. strigilecula were common. The rest were rare.

The bivalves which occurred in the area of the hypersaline lagoons include T. americana, P. cinnabarensis, A. meeki, P. fontenellensis, Corbula sp., M. subimbricatus, O. strigilecula, C. platessiformis and M. whitei. The bottom fauna was less diverse and less abundant than the P. subcompressa zone. This would be expected as faunal diversity decreases in marginal marine environments where conditions of salinity, pH, and water temperature change rapidly. The benthos which inhabited the flushed lagoons apparently were opportunistic species in the sense of rapidly immigrating into the lagoons whenever



Text-fig. 9 Bajocian palcogeography and bivalve paleobicgeography.

brief intervals of normal marine conditions prevailed. The fauna was dominated by T. americana. The remaining bivalves were rare except for M. whitei.

The coral Actinastrea hyatti was abundant with these bivalves. It occurred in local patches and was apparently successful in setting up housekeeping in the shallow waters of the marginal lagoons.

In summary, three distinct faunal associations were present during Bajocian time (pl. 21); the Camptonectes stygius fauna on the outer open shelf, the Pleuromya subcompressa fauna on the inner open shelf, and the Trigonia americana fauna in the marginal lagoons (text-fig. 9). Adverse conditions in the hypersaline lagoons and outer part of the open shelf are reflected by the lower faunal diversity and lower abundance of the C. stygius and T. americana associations as compared with the P. subcompressa association.

The overall picture of marine life which inhabited the shelf environment during the Middle Jurassic is one of greater diversity than was attained at any time during the Late Jurassic.

Bathonian.-- Following deposition of Rich deposits and the claystone beds of the Gypsum Spring Formation, Bathonian shallowing reestablished widespread hypersaline conditions on the Wyoming shelf and in the lagoons. Shallowing is indicated by oolitic beds at the top of the Rich Member and by broken shell fragments and intraclasts in the lower part of the Boundary Ridge Member. Hypersalinity is indicated by gypsum which forms the top of the Gypsum Spring Formation, and by maroon calcareous shale in the Boundary Ridge Member of the Twin Creek Limestone. Hypersaline conditions persisted in northern and west-central Wyoming, while transient hypersaline lagoons and marginal marine conditions prevailed in westernmost Wyoming (Imlay, 1967).

Scarcely any bottom dwellers survived. I found only Camptonectes stygius in the Boundary Ridge Member and Imlay (1967) notes that very few identifiable species have been found except for fragments of species of Camptonectes, Myophorella montanaensis, Vaugonia conradi,

Trigonia ellegantissima, and species of Astarte.

Upper Jurassic

Earliest Callovian sedimentary environments. -- Earliest Callovian was a time of marked deepening of water across the Wyoming shelf (text-fig. 10). The deposits include the Watton Canyon Member of the Twin Creek Limestone in western Wyoming, the lower oolitic sandstone member of the "Lower Sundance" in northern Wyoming, the lower oolitic deposits of the Stockade Beaver Shale, and the Canyon Springs Sandstone in south-central and eastern Wyoming and the Black Hills.

In westernmost Wyoming, the basal bed of the Watton Canyon Member is a poorly washed oobiosparite containing shell fragments indicating turbulent water conditions. Throughout western Wyoming, oolite beds occur at the base of the member and often throughout it (Imlay, 1967). Tranquil bottom conditions persisted after the deepening and the area was again the scene of rapid formation of lime mud.

The initial deepening phase in northern Wyoming is represented by the lower oolitic sandstone member of the "Lower Sundance" at Thermopolis and Lovell. In the northern part of the Wind River Basin the sequence of earliest Callovian deposits are much thicker than found elsewhere at the base of the Stockade Beaver Shale. Nearly the entire sequence of limestone and claystone in the lower part of the Stockade Beaver Shale at Maverick Spring contains sedimentary grains indicative of turbulent water, such as pellets, oolites, tightly packed shell fragments, and composite grains.

Away from the Maverick Spring area (e.g., Thermopolis to the north and Bull Lake to the south) the lower oolite sequence is thinner. This suggests that turbulent water conditions were more prevalent and the rate of subsidence was greater at Maverick Spring.

In south-central and eastern Wyoming, the Canyon Springs Sandstone Member formed along the sea margin. The transition from the lower massive cross-bedded sandstone unit to the upper flat-bedded

symmetrically rippled oolitic sandstone unit of the Canyon Springs Sandstone may mark a change from terrestrial to littoral or shallow sublittoral environment.

In summary, deepening and encroachment of the sea across the Wyoming shelf in earliest Callovian time everywhere resulted in limestone, claystone, or sandstone beds containing sedimentary grains indicative of turbulent water.

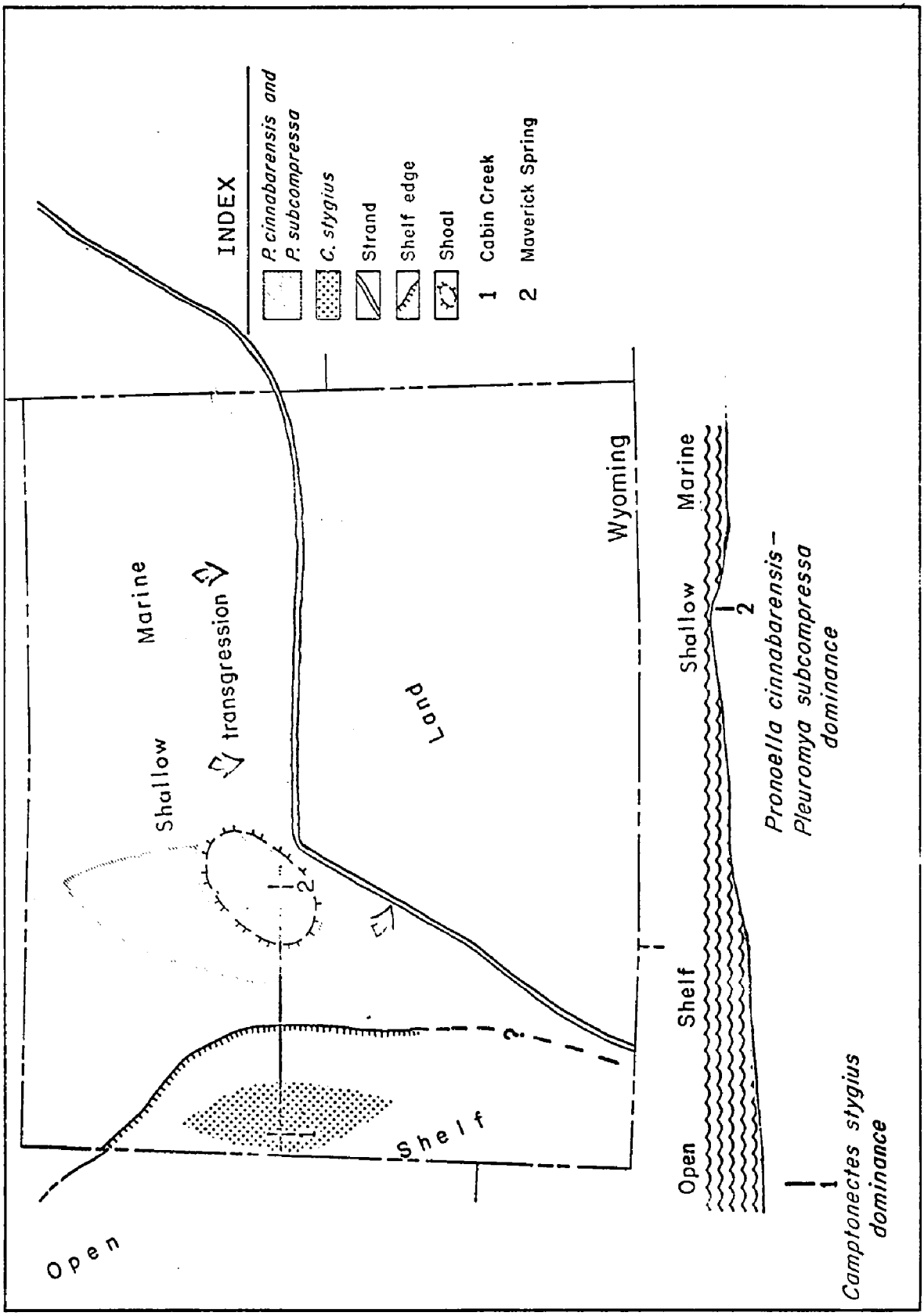
Limestone characterized the offshore open shelf of westernmost Wyoming, calcareous claystone was forming in the shallow marine environments in northern and west-central Wyoming, and sandstone dominated the southeastern shoreline.

Earliest Callovian bottom fauna.-- The earliest Callovian benthos of the open shelf was not diverse. Typically, it included only a few organisms of which Camptonectes stygius was the most abundant (text-fig. 10). The rest of the epifauna included Ostrea strigilecula and Lima sp., which were rare. Imlay (1967) reports the occurrence of Gryphaea nebrascensis and Modiolus subimbricatus. The infauna was represented by Myophorella montanaensis, Trigonia ellegantissima, Vaugonia conradi, Astarte meeki, Quenstedtia sublevis, and Myopholas hardyi.

In general, in contrast to the diversified Middle Jurassic shelf fauna, this shelf fauna was sparse.

Farther east in the shallow marine environment the benthos was more diverse. The bivalves included Modiolus subimbricatus, Ostrea strigilecula, Camptonectes platessiformis, Pleuromya subcompressa, Vaugonia conradi, Pronoella cinnabarensis, Tancredia sp., Trigonia ellegantissima, Astarte packardi, Thracia sp., Mactromya? sp., Trigonia sp., Meleagrinella curta, Vaugonia sp., Mytilus sp., Tancredia warrenana and Gryphaea nebrascensis.

P. cinnabarensis and P. subcompressa were the dominant animals (text-fig. 10). These bivalves are not found at every locality. All of them except Mytilus sp. and Tancredia warrenana occur at



Text-fig. 10 Earliest Callovian paleogeography and bivalve paleobiogeography.

Maverick Springs. In the eastern Bighorn Basin only M. subimbricatus, O. stigilecula, C. platessiformis, P. subcompressa, and V. conradi occur. In the Black Hills, only T. warrenana, M. curta, and V. conradi occur. Later in the Callovian, M. curta would dominate the benthos throughout southeastern Wyoming (text-fig. 11, pl. 20).

This paucity of bivalves away from Maverick Spring is general throughout southeastern and central Wyoming. Shoaling might have existed in the vicinity of Maverick Spring and allowed for enough time for a diverse fauna to become established in contrast to the sparse biota in the rest of the shallow marine areas along the shoreline.

In summary, the earliest Callovian fauna was characterized by a low-diversity Camptonectes stygius fauna which inhabited a lime mud bottom of the open shelf in westernmost Wyoming, and a more diverse Pronoella cinnabarensis - Pleuromya subcompressa fauna which inhabited the shallow marine areas of the eastern shoreline.

Early Callovian sedimentary environments.-- In early Callovian time a submarine topographic high (Sheridan Arch of Peterson, 1957) formed across the Wyoming shelf from approximately the Lander area northeast through Buffalo and into Montana. It may have initiated extensive shoal areas (an expansion of the Maverick Spring area) that had a major effect on the spatial distribution of sedimentary environments and their contained fauna (text-figs. 11-13).

Most of the Wyoming shelf was under water (text-fig. 11). Rapid deposition of lime mud occurred on the open shelf of westernmost Wyoming to form the thick limestone beds of the Leeds Creek Member. Except near the arch, the lime muds grade laterally into calcareous clay muds across the Wyoming shelf to produce the Stockade Beaver Shale and middle shale member of the "Lower Sundance."

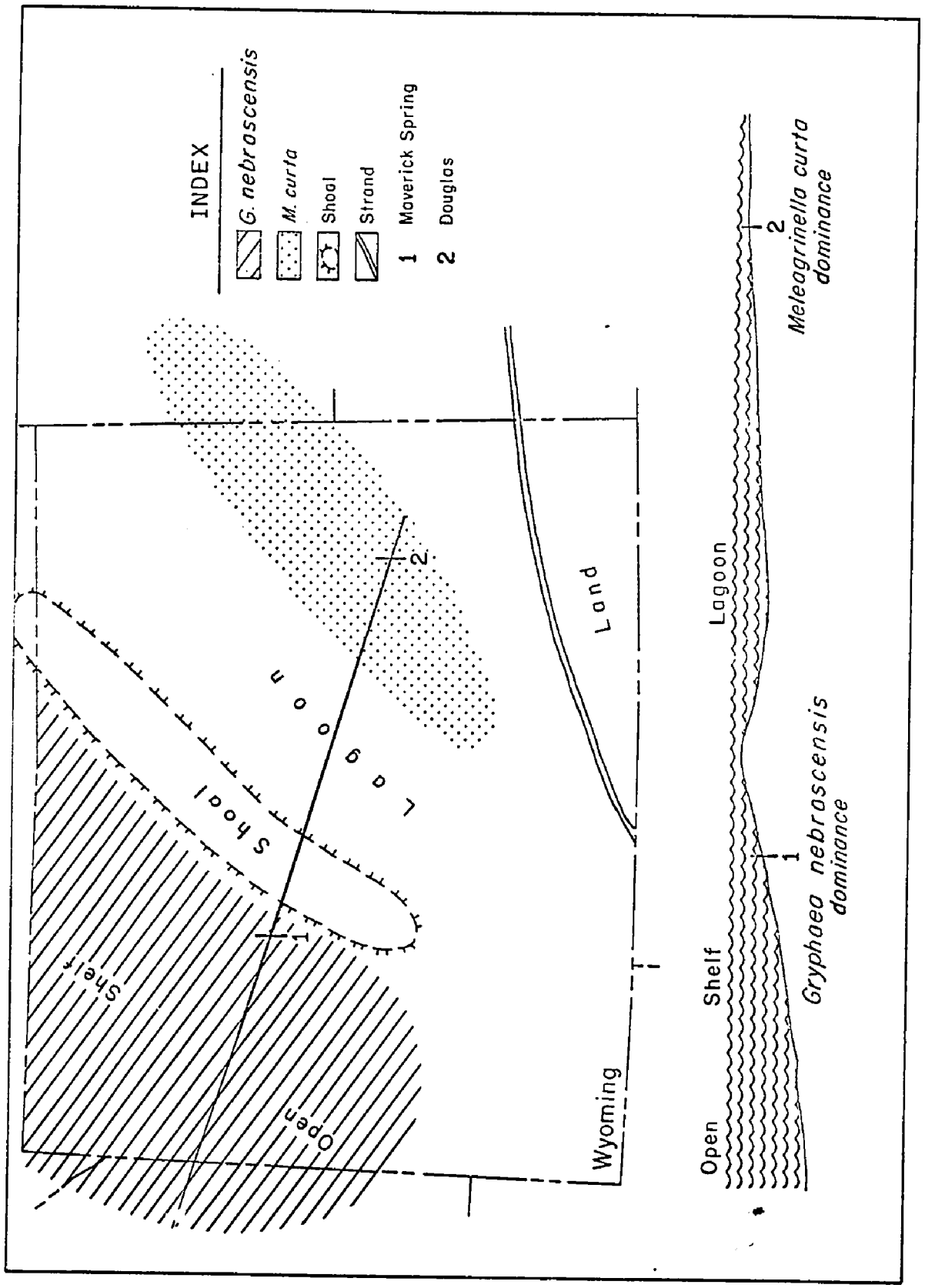
The middle shale member of the "Lower Sundance" thins to almost zero in the area of the arch (i.e., Lander, Vinceants Ranch, Thermopolis, Hyattville, and Tensleep) and sandstone dominates the facies. Southeast of the shoals, sandstone and green to olive-gray shale

were deposited to form the Stockade Beaver Shale and Canyon Springs Sandstone. These deposits were laid down in shallow water, as attested by a variety of sedimentary structures such as cross-bedding and ripple marks.

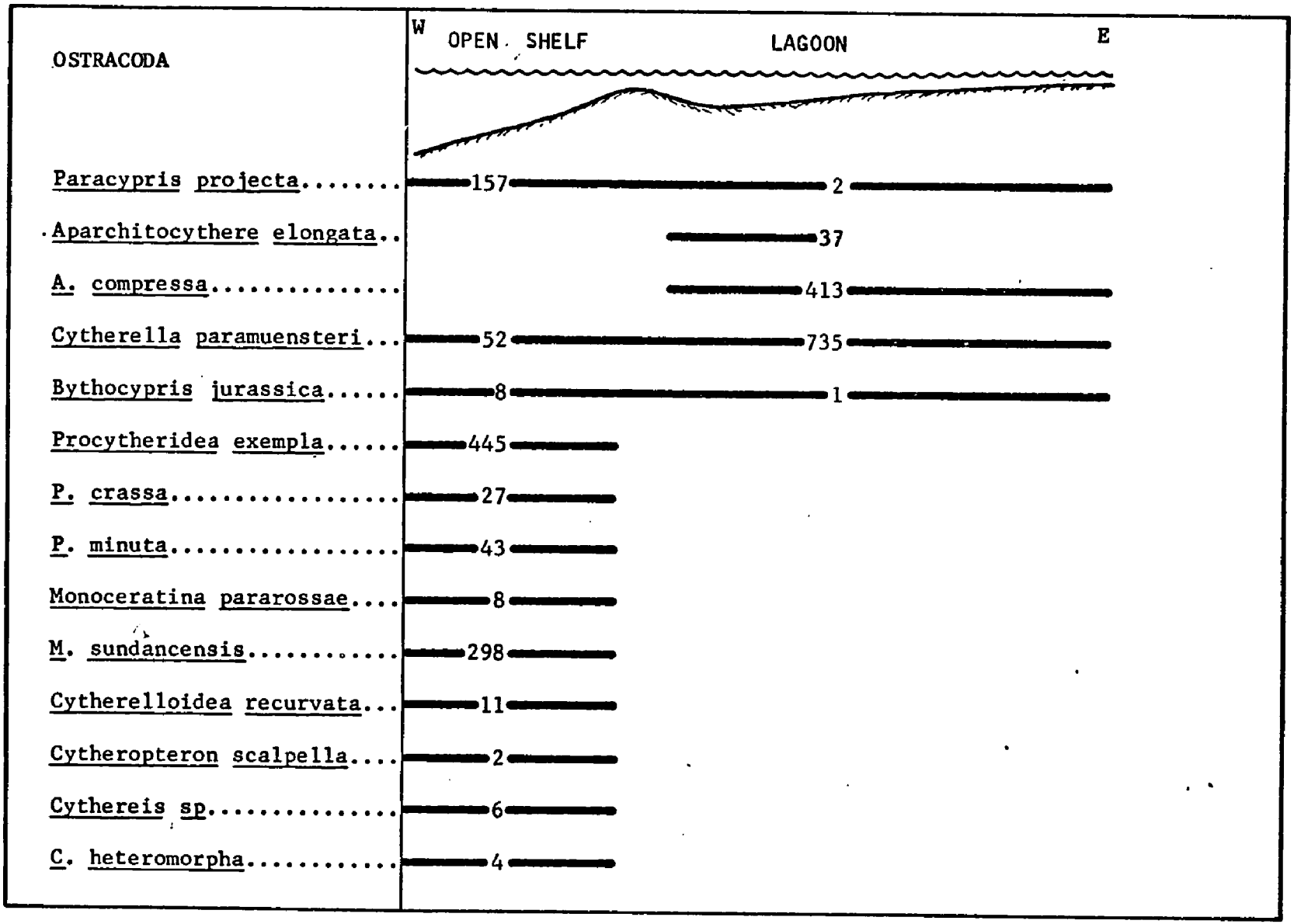
Early Callovian bottom fauna.-- Two distinct faunas existed. Northwest of the arch the fauna was dominated by Gryphaea nebrascensis (text-fig. 11; pls. 20,21), which took over the earlier-established Camptonectes stygius area. The G. nebrascensis association included O. strigilecula, C. stygius, C. platessiformis, M. subimbricatus, Astarte meeki, A. packardi, Grammatodon haguei, Pronoella cinnabarensis, and Myopholas hardyi. None of them were anywhere near as abundant as G. nebrascensis. Imlay (1967) also listed Plicatula sp., Lima occidentalis, Ctenostreon cf. C. gikshanensis, Lopha sp., Trogonia americana, T. ellegantissima, Quenstedtia sublevis, Protocardia cf. P. schucherti, and Platymyoidea rockymontana from the Leeds Creek Member. I found none of these species, and they were apparently also rare elements of the shelf bottom fauna.

Southeast of the arch Meleagrinella curta completely dominated the benthos (text-fig. 11; pl. 20). The other members of the fauna included Ostrea strigelecula, Gryphaea nebrascensis, Camptonectes platessiformis, Nucula sp., Lima sp., Myophorella montanaensis, Tancredia warrenana, Tancredia sp., Vaugonia conradi, Myophorella montanaensis, and Quenstedtia sublevis. They were not abundant.

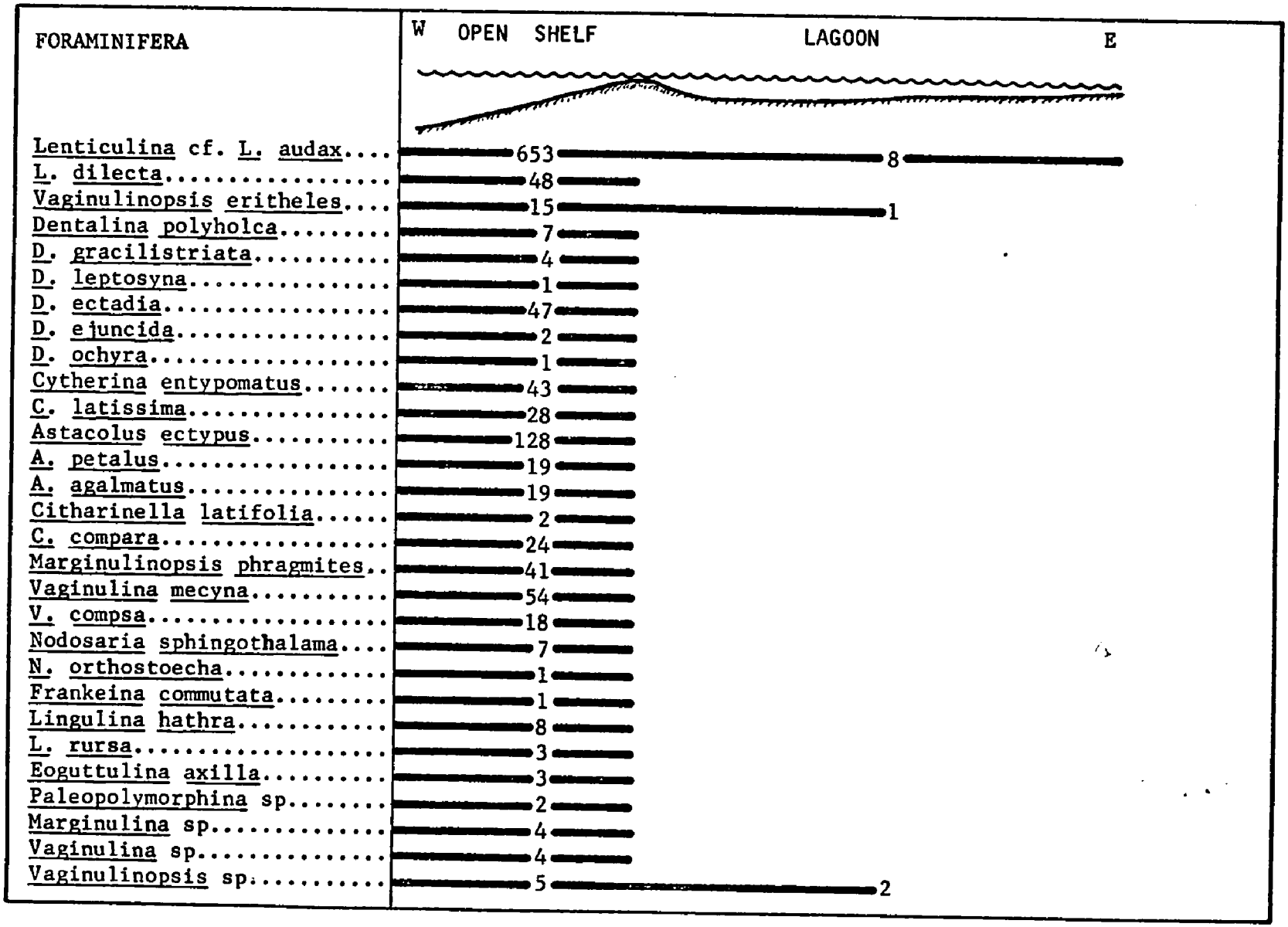
Early Callovian microfauna.-- The distribution of foraminifera and ostracods is shown in text-figs. 12 and 13. Their spatial distribution was obviously controlled by the presence of the Sheridan Arch. The outstanding feature is the near exclusion of foraminifera southeast of the arch and the dominance there by large numbers of just a few kinds of ostracods. Of the ostracods, Aparchitocythere compressa and A. elongata were restricted to the southeast side of the arch while Procytheridea exempla, P. crassa, P. minuta, Monoceratina pararossae, M.



Text-fig. 11 Early Callovian paleogeography and bivalve paleobiogeography.



Text-fig. 12 Paleobiogeography of early Callovian Ostracoda.



Text-fig. 13 Paleobiogeography of early Callovian Foraminifera.

sundancensis, Cytherelloidea recurvata, Cythereis sp., C. heteromorpha, and Cytheropteron scalpella were restricted to the northwest side of the arch.

These two faunas are in very close agreement with the A. compressa and P. exempla biofacies of Peterson (1954). In that paper Peterson suggests that the arch acted as a barrier separating cool water of the Powder River Basin from warm water of the "Twin Creek Trough." He suggests that the Powder River Basin was the early phase of the Mesozoic trough system with the water coming from the Arctic and that the "Twin Creek Trough" might have been the final phase of the Paleozoic trough system which contained warm water from the south.

Peterson also suggests that since cooler water faunas contain the ostracod Cytherella in abundance (Swain, personal communication to Peterson) the presence and great abundance of C. paramuensteri southeast of the arch suggests that cooler water was present there than north of the arch. Also, the decrease in faunal diversity southeast of the arch is used to support his contention.

On the contrary, I believe that the controlling factor which determined the faunal distribution on both sides of the arch was salinity and not primarily temperature. First of all, the marine Jurassic rocks in the Western Interior were deposited in an embayment which spread eastward from the Pacific across northwestern United States and parts of Canada. The United States part of the embayment may have been bordered on the west by a landmass from Bajocian to Oxfordian (Imlay, 1967). This might preclude a connection with a southern warm-water source area.

Secondly, the inference that all species of Cytherella inhabit cool water is not very sound (Neale, 1964). Whereas some species of Cytherella are prominent in cool water, others can tolerate warm water (Kornicker, 1963).

Thirdly, the water southeast of the arch may have been very shallow. This broad expanse of shallow water would have resulted in

warm-water conditions, and water here would be expected to attain higher temperature than that north of the arch.

Foraminifera and Ostracoda are more abundant in numbers of individuals in marginal marine environments whereas the number of species increases away from the shore line (Walton, 1964; Bandy & Arnel, 1960; Swain, 1955). Limited data also suggest that the foraminifera/ostracod ratio is lowest near shore (Bandy, 1964; Upshaw et al., 1966), and that ostracods dominate the microfauna to the exclusion of foraminifera in hypersaline lagoons (Upshaw et al., 1966). Some of these trends are apparent in the Sundance microfauna.

The great number of foraminifera and ostracod species northwest of the arch indicates prevailing normal marine conditions there. Southeast of the arch, foraminifera are excluded except for a sparse fauna of Vaginulinopsis sp., Lenticulina cf. L. audax, and L. dilecta. The ostracods occurring southeast of the arch show large numbers of individuals belonging to a few species. This decrease in faunal diversity of both groups is indicative of marginal marine conditions, in this case lagoonal environments. As discussed later, the lagoons persisted during the Callovian and were later the sites of deposition of redbeds and gypsum.

The salinity of the lagoons may have been greater or less than the shelf environment, or could have fluctuated with seasonal temperature change (Emery et al., 1957). If distributary runoff was great, the tendency for the restricted water to become hypersaline would have been offset resulting in brackish conditions. If runoff was slight, hypersaline conditions would have existed. Although the lack of gypsum in the Stockade Beaver Shale suggests that the water was not hypersaline, the salinity may well have exceeded the tolerance level of most of the biota and yet been too low to result in evaporite formation.

The abundance of Meleagrinella curta and associated bivalves southeast of the arch may argue against persistent hypersalinity. Indeed, if hypersalinity were prevalent Ostrea strigilecula and Gryphaea

nebrascensis should not have occurred along with M. curta at Newcastle because oysters are endemic to marine waters of lowered salinity (Yonge, 1966). It is highly improbable that M. curta inhabited brackish water in one area (i.e., Newcastle) and hypersaline water everywhere else.

On this account, the existence of brackish-water conditions in the lagoons is favored. This does not preclude the possibility of salinity fluctuating greatly over short periods of time, which would also have resulted in the sharp faunal break at the area of shoaling (i.e., Sheridan Arch).

Middle Callovian sedimentary environments. -- In middle Callovian time, following deposition of the Leeds Creek Member of the Twin Creek Limestone, the Stockade Beaver Shale, and the middle shale member of the Sundance Formation, there began a marked change in regional sedimentation throughout the Western Interior. To the west a new clastic source area began to develop which would provide the sands of the Preuss Sandstone and Stump Sandstone that were later deposited on lime muds of the Twin Creek Limestone. In addition, the Sheridan Arch continued to restrict circulation across most of Wyoming and became more effective with shallowing. The arch and general shallowing caused widespread hypersaline conditions throughout south-central Wyoming and the Black Hills where redbeds of the Lak were deposited.

The shallowing near middle Callovian time resulted in the formation of extensive turbulent shallow-water deposits characteristic of upper sublittoral and littoral environments over the entire Wyoming shelf. Along the southeastern Wyoming shore line the Hulett Sandstone of the Sundance Formation was deposited. Cross-bedding, ripple marks, oolites, and broken shells attest to the shallowness and turbulence of the water.

The upper sandstone member of the "Lower Sundance" was deposited over the Sheridan Arch. Northwest of the arch this member pinches out but at Lovell it may be represented by several feet of oolitic sandstone.

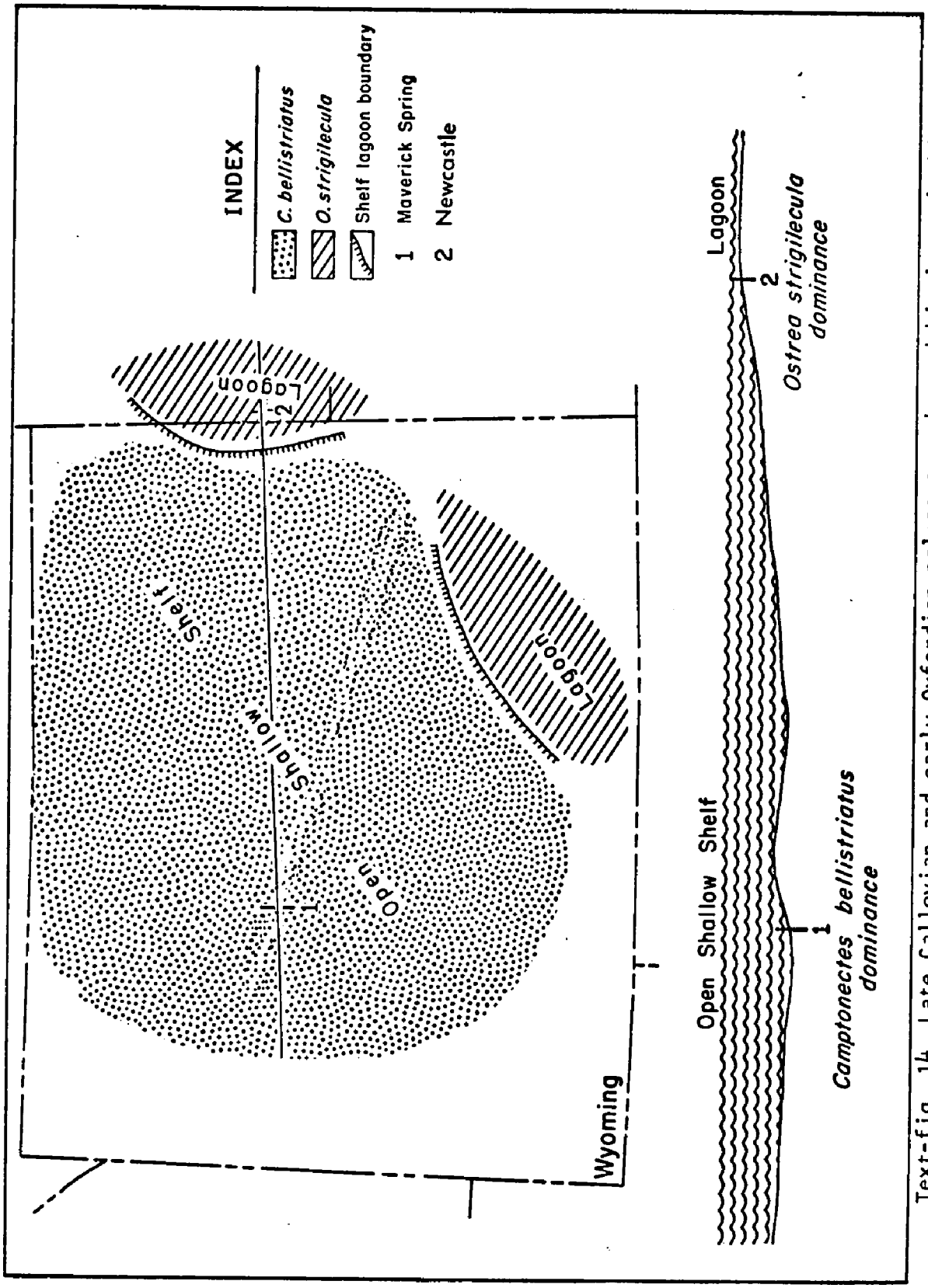
Shallowing of the shelf environment along westernmost Wyoming resulted in deposition of oolitic sandstone and ripple-marked limestone of the Giraffe Creek Member of the Twin Creek Limestone. The persistence of the Sheridan Arch, which effectively cut off water interchange between central Wyoming and northwestern Wyoming resulted in the development of a hypersaline basin in which the redbeds and gypsum of the Lak Member of the Sundance Formation were deposited. The redbeds were restricted to the southeast side of the arch while normal marine deposits continued to form north of it. The lack of a benthic fauna in the Lak Member across central Wyoming at this time was due to hypersalinity.

Middle Callovian bottom fauna.-- The benthos which habited the sands of middle Callovian constituted two dominant faunas. Tancredia sp. occurred along the southeastern shore line and Meleagrinella curta was common to the Sheridan Arch area. The Tancredia sp. fauna inhabited the sands of the Hulett Sandstone and Upper Sandstone Member of the "Lower Sundance." The fauna included Tancredia transversa, T. warrenana, Tancredia sp., Quenstedtia sp., Meleagrinella curta, Mytilus whitei, and Camptonectes platessiformis.

Tancredia preferred sandy substrates and dominated the sandy marginal marine environments not only during middle Callovian but in early Oxfordian as well. It appears to have had an affinity for intertidal sands because Waage (1968) also noted its occurrence in intertidal sands of the Cretaceous Fox Hills Formation.

In northern Wyoming the fauna was dominated by Meleagrinella curta, although Tancredia was common. Camptonectes platessiformis was rare and Mytilus whitei occurred in local patches at Thermopolis.

Late Callovian and Early Oxfordian sedimentary environments.-- Shelf deepening and possibly transgression occurred in late Callovian time (text-fig. 14). During this time, the Pine Butte Member and Redwater Shale was deposited throughout central, southern, and eastern



Text-fig. 14 Late Callovian and early Oxfordian paleogeography and bivalve paleobiogeography.

Wyoming and the "Upper Sundance" in northern Wyoming. The effect of the western clastic source area was now evident, for sand became more prevalent to the west until it was the predominant lithology at such localities as Bull Lake, Maverick Spring, and Lovell. At the same time, sands of the Stump Sandstone were forming in western Wyoming.

The Sheridan Arch was submerged deep enough to prevent it from acting as an effective barrier across the Wyoming shelf (text-fig. 14).

Microfauna.-- Ostracods and foraminifera were abundant during late Callovian and early Oxfordian and ranged across the entire shelf although many were local in their occurrence (text-fig. 15). A sharp faunal break, like that of early Callovian time, did not develop across the Wyoming shelf, probably because the water was deeper. The shelf was free of barriers, and normal marine conditions existed nearly everywhere except in areas that may have been lagoons along the most southeastern portion of the state. Decrease in the diversity of microfauna and change in the macrofauna suggest that water was much shallower here than elsewhere.

Arenaceous foraminifera make up 45 percent of the total foraminifera fauna. In contrast, arenaceous forams were virtually absent in the early Callovian fauna. This increase in arenaceous forams might have been caused by lower water temperature in Late Jurassic time, which resulted in a decrease in calcium carbonate availability. Arenaceous foraminifera increase in numbers in water of low calcium carbonate availability, inasmuch as they do not need such a high concentration of carbonate for test construction as do the calcareous forms (Greiner, 1970).

As discussed by Peterson (1957), other lines of evidence also suggest a general cooling of water temperature during this time including: decrease in limestone deposition in the Oxfordian as compared with the Middle Jurassic and Callovian, and southward migration of belemnites which were inhabitants of cool water (Urey, 1951). Although this

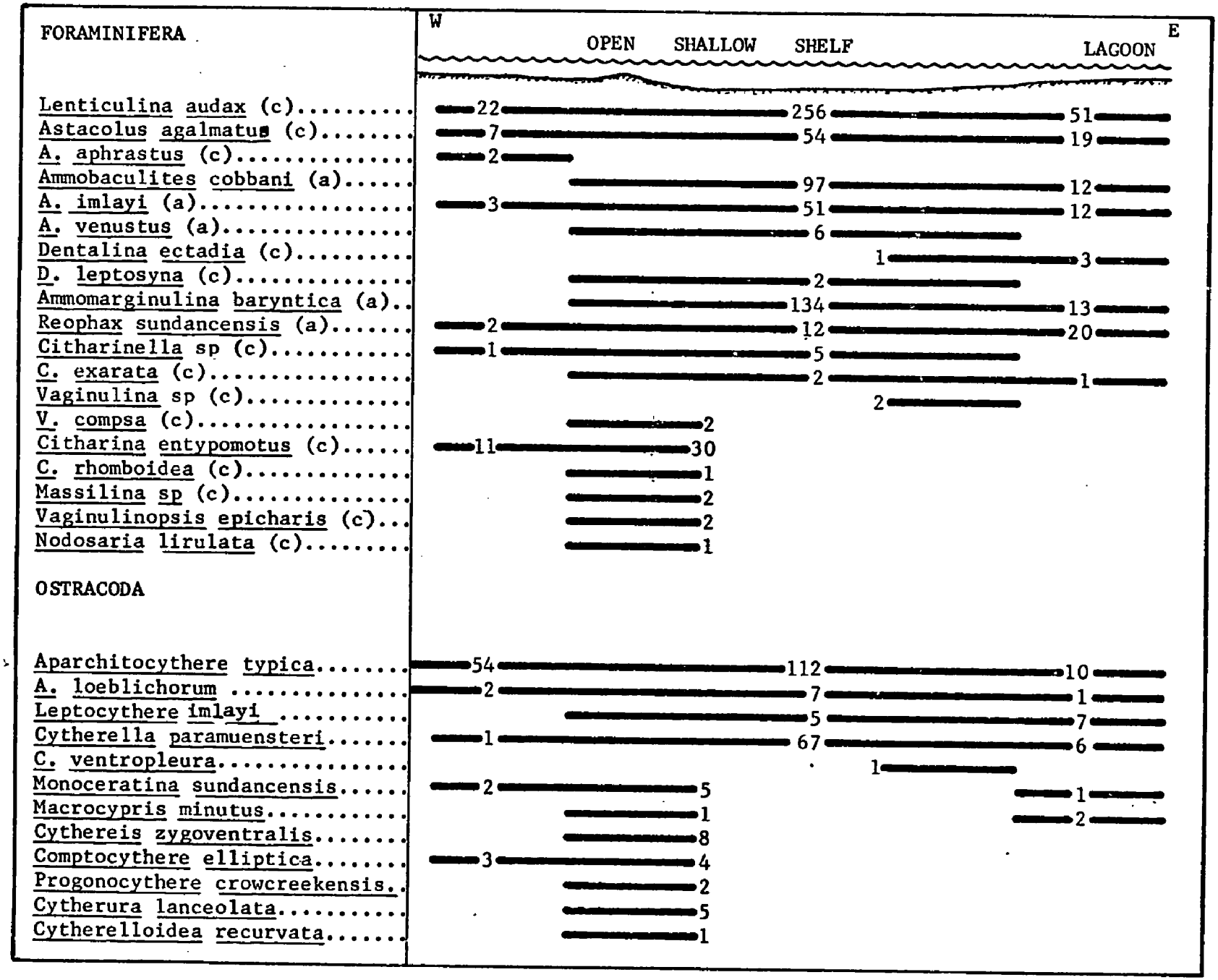
evidence is not conclusive, it does suggest a Late Jurassic cooling trend as does the abundance of arenaceous foraminifera.

Cooling of the Arctic seas is suggested by Imlay (1965) as a mechanism for LateJurassic faunal differentiation. However, this is not the only possible cause. Hallam (1969) suggests that a decrease in salinity rather than temperature was the mechanism for Jurassic faunal differentiation. He proposes the existence of an extensive inland sea of slightly reduced salinity in the Northern Hemisphere serving as the source area.

A reduction in either salinity or temperature or a combination of the two could have reduced the calcium carbonate availability, thus causing faunal changes. A reduction in temperature is favored because the diverse marine benthos of the Oxfordian across the Wyoming Shelf probably would not have existed under abnormal conditions of salinity. Also, the prolonged maintenance of a northern sea of reduced salinity seems improbable as water exchange with bordering seas would tend to restore the normal salt concentration.

Late Callovian and Early Oxfordian macrofauna.-- Two dominant faunas were present across the shelf. The Camptonectes bellistriatus fauna across most of Wyoming and the Ostrea strigilecula fauna in southeastern Wyoming, eastern Wyoming and the Black Hills (text-fig. 14; pls. 20, 21). The C. bellistriatus fauna included Ostrea strigilecula, O. engelmanni, Tancredia transversa, Tancredia sp., Pleuromya newtoni, Pleuromya sp., Grammatodon inornatus, Gryphaea nebrascensis, Modiolus formosa, Astarte packardi, Modiolus sp., Pronoella sp., Vaugonia sturgisensis, Pholadomya sp., Idonearca sp., Alectryonia procumbens, and the brachiopod Kallirhynchia myrina. Of these, only O. strigilecula and A. procumbens were abundant.

A. procumbens was geographically restricted; it occurred only at Maverick Spring at the base of the Redwater Shale. This small local population was either killed off or migrated to other suitable habitats when the water became deeper. Kallirhynchia myrina preferred sandy



Text-fig. 15 Paleobiogeography of late Callovian and early Oxfordian Foraminifera and Ostracoda. Index to Foraminifera. a = arenaceous, c = calcareous.

substrates along the western portion of the shelf and occurred along with C. bellistriatus.

The O. strigilecula fauna included Tancredia sp., Meleagrinella curta, Camptonectes bellistriatus, Nucula sp., and Astarte sp. They were all rare. Ostrea strigilecula makes up entire shell-hash beds deposited by waves or currents and occurs in living position in limy sand beds which may represent lagoonal oyster banks.

Oxfordian sedimentary environments.-- Slow regression brought an end to clay mud deposition and C. bellistriatus dominance on the shelf in late early Oxfordian.

Throughout south-central and southeastern Wyoming, regressive beach and dune deposits of the Windy Hill Sandstone formed at this time. In central Wyoming, the break between shale deposition and regressive sands was represented by much of the sandstone of the "Upper Sundance." In northern and western Wyoming, this change is not evident, since sand deposition continued here for some time.

Oxfordian bottom fauna.--Camptonectes bellistriatus fauna gave way to a Tancredia fauna, which inhabited the regressive marginal marine and littoral sand environments. The fauna included Tancredia transversa, Tancredia sp., Meleagrinella curta, Ostrea strigilecula, Camptonectes sp., Vaugonia sturgisensis, Pleuromya sp., Platymyoidea sp., Modiolus sp., Idonearca sp., and the brachiopod Kallirhynchia myrina. Only Tancredia and Ostrea were abundant.

The fauna occurred in sandstone throughout Wyoming and apparently migrated northward with the sand environment as regression progressed.

Oxfordian regression was slow and not everywhere marked by sandy beaches. The contact with the overlying Morrison Formation is gradational at many localities as the marine environment gradually gave way to fluvial and lacustrine environments of the Morrison.

SUMMARY AND CONCLUSIONS

The Middle and Upper Jurassic sediments of Wyoming and South Dakota are well suited for a paleoecologic analysis because the sediments are varied and contain a diversified bottom fauna of bivalves, ostracods, and foraminifera.

My aim was six-fold: (1) to determine the life modes of the bivalves; (2) to establish the time-space distribution of bivalve associations; (3) to analyze the microfauna; (4) to interpret sedimentary environments; (5) to combine 2, 3, and 4 to obtain the total environmental picture; and (6) to assess the effect of bottom topography (Sheridan Arch) on animal and environment distribution. Text-fig. 16 shows the time-space distribution of marine Jurassic environments represented by this study.

The bivalves were divided into five feeding groups; infaunal siphon feeders, labial palp deposit feeders, infaunal non-siphonate suspension feeders, infaunal mucus-tube feeders, and epifaunal suspension feeders. Consideration of the function of shell shape and significance, burial position, and comparison of the fossil with a living taxonomic relative were useful in determining life-modes.

The bivalves were arranged into major associations each with its particular paleobiogeography.

In Bajocian time three bivalve associations existed. The Camptonectes stygius fauna inhabited the outer shelf in westernmost Wyoming in an area of rapid lime-mud deposition (Sliderock and Rich Members of the Twin Creek Limestone). The Pleuromya subcompressa fauna occurred farther shoreward where mud deposition was not as great. The Trigonia americana fauna occurred in lagoons along the eastern shoreline, sites of Gypsum Spring Formation deposition (pl. 21).

In Callovian time Camptonectes stygius and Pronoella cinnabarensis - Pleuromya subcompressa (pl. 20) initially dominated the bottom fauna in western Wyoming and along the shoreline respectively but gave

way to Gryphaea nebrascensis and Meleagrinella curta (pls. 20, 21).

The Sheridan Arch was a dominant feature on the Wyoming shelf during early and middle Callovian and acted as a marine barrier which determined the geography of bivalves and microfossils.

The Gryphaea nebrascensis fauna was restricted to an area of normal marine conditions northwest of the Arch (attested by the abundance and variety of foraminifera and ostracods) in which the Leeds Creek Member of the Twin Creek Limestone, the "Lower Sundance," and Stockade Beaver Shale (at Bull Lake and Maverick Springs) were deposited.

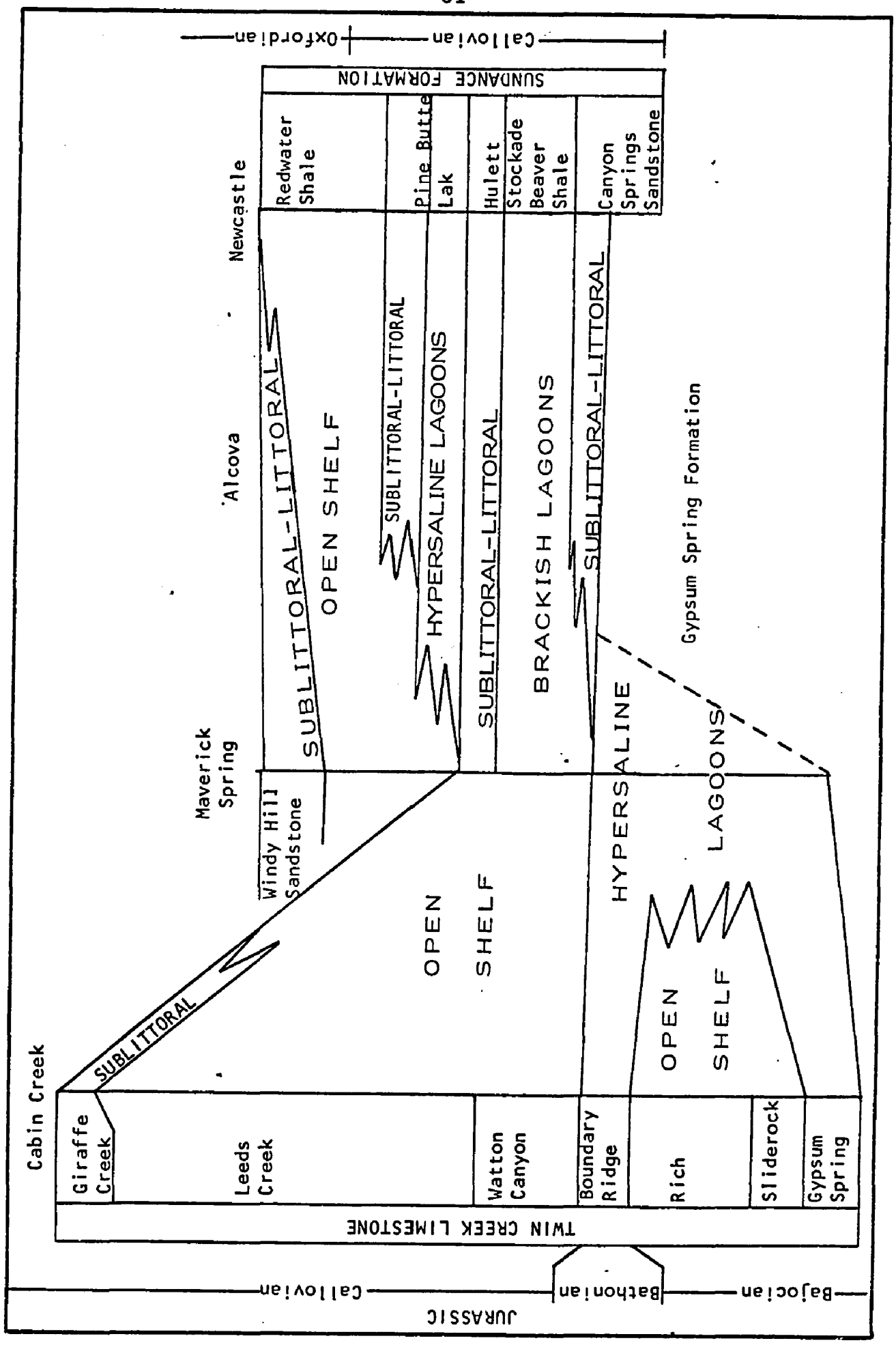
The Meleagrinella curta fauna was restricted to brackish lagoons southeast of the Arch (attested by the absence of foraminifera and high faunal dominance of ostracods), in which the Canyon Springs Sandstone, Stockade Beaver Shale, Hulett Sandstone, and Lak redbeds were deposited.

In late Callovian time, the water on the Wyoming shelf deepened. The Sheridan Arch ceased being a major influence, and the Camptonectes bellistriatus fauna (pls. 20, 21), ostracods, and foraminifera ranged across the entire shelf. The abundance of arenaceous foraminifera suggests that the water was cooler than earlier in the Jurassic.

Sediments formed at this time were muds and sands of the Pine Butte, Redwater Shale, and Windy Hill Sandstone Members of the Sundance Formation in central and eastern Wyoming, the "Upper Sundance" in northern Wyoming, and the Preuss and Stump Sandstones in western Wyoming.

Oxfordian regression ended the marine era in Wyoming and South Dakota and the non-marine Morrison Formation began to form.

The sediments of the Twin Creek Limestone and Sundance Formation formed in a variety of open shelf, hypersaline and brackish lagoon and littoral environments. Shallow water and bottom topography resulted in local thinning and pinching out of strata, rapid vertical lithologic changes, abrupt changes in biota, and sedimentary features such as oolites, pellets, clasts, broken shell fragments, chert pebbles



Text-fig. 16 Summary diagram showing the time-space distribution of middle and upper Jurassic environments.

and bored surfaces. Contrary to previous interpretations, these features do not represent regional disconformities nor are major intervals of time unrepresented.

The incorporation of data (sediments, bivalves, and microfossils) has proved to be useful in defining Middle and Upper Jurassic environments in Wyoming and South Dakota.

APPENDIX A

Plates 1-12, photographs of stratigraphic sections and rock thin-sections.

Plate 1

Fig. 1. Minnekahta. Nugget Sandstone (1) overlain by the Canyon Springs Sandstone (2), Stockade Beaver Shale (3), and Hulett Sandstone (4) of the Sundance Formation.

Fig. 2. Freezeout Mountains. Sundance Formation with the Canyon Springs Sandstone (1), Hulett Sandstone (2), and Lak Member. The Stockade Beaver Shale is absent between the Canyon Springs Sandstone and Hulett Sandstone because of nondeposition.

Fig. 3. Rapid City. Sundance Formation. The thin sandstone beds of the upper part of the Stockade Beaver Shale (1) grading into the Hulett Sandstone (2).

Fig. 4. Douglas. Entire exposure of Sundance Formation. Canyon Springs Sandstone (1), Stockade Beaver Shale (2), Hulett Sandstone (3), Lak Member (4), Pine Butte Member (5), and Redwater Shale (6).

PLATE 1

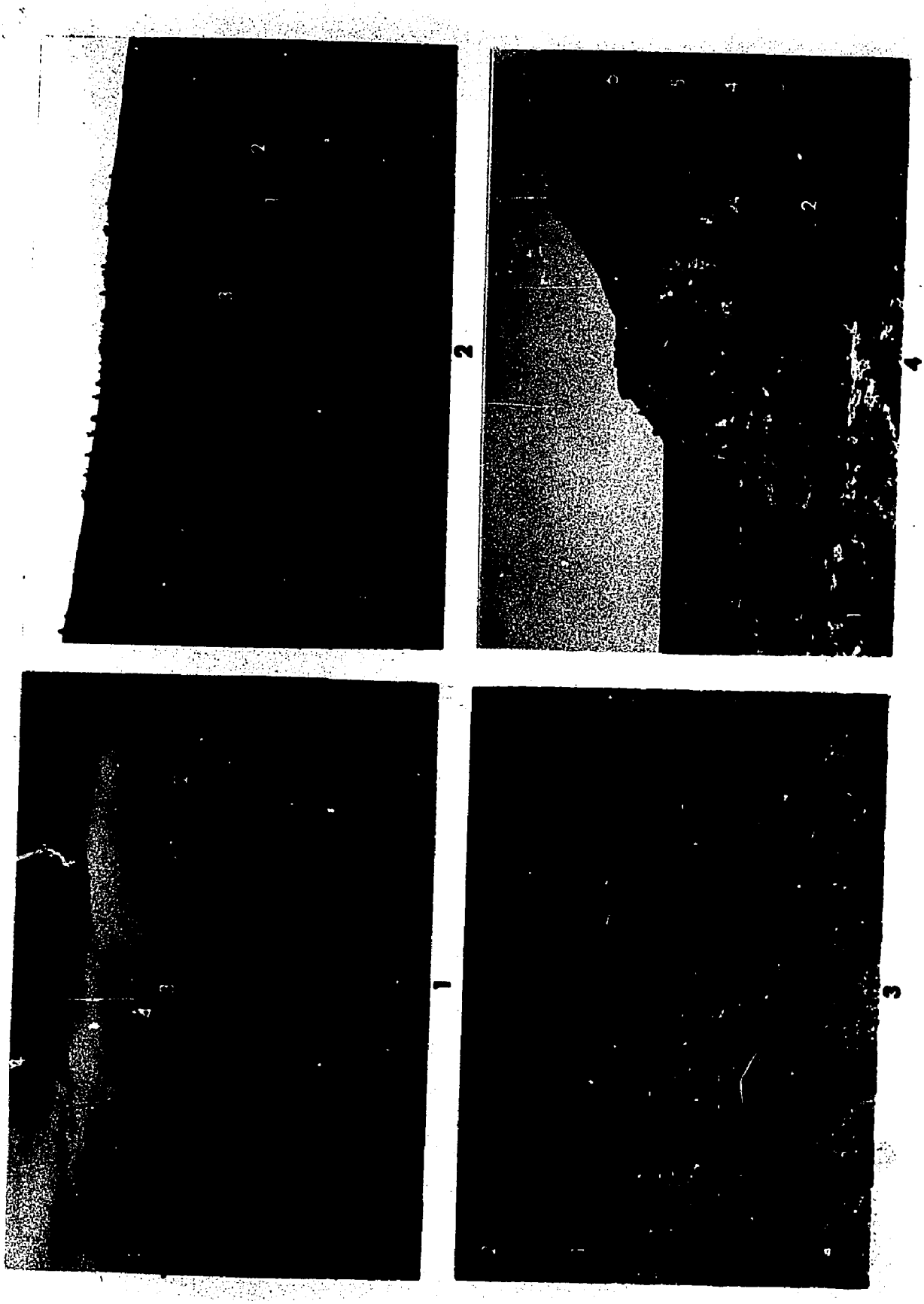


Plate 2

Fig. 1. Packed poorly washed biosparite. Allochems include bivalve and echinoderm fragments, oolites, and pellets. 5X. Gypsum Spring Formation, Cody.

Fig. 2. Poorly washed sandy packed oobiosparite. Allochems include oolites, pellets, bivalve and echinoderm fragments. 5X.
Stockade Beaver Shale, Sundance Formation, Maverick Spring.

Fig. 3. Biopelmicrite. Allochems include bivalve and echinoderm fragments, ostracods, and pellets. 5X.
Stockade Beaver Shale, Sundance Formation, Maverick Spring.

Fig. 4. Poorly washed sandy oosparite. Allochems include oolites, gastropod, bivalve, and echinoderm fragments. 5X.
Stockade Beaver Shale, Sundance Formation, Bull Lake.

Fig. 5. Calcareous sandstone with oyster shell fragments. 5X.
Stockade Beaver Shale, Sundance Formation, Rapid City.

PLATE 2

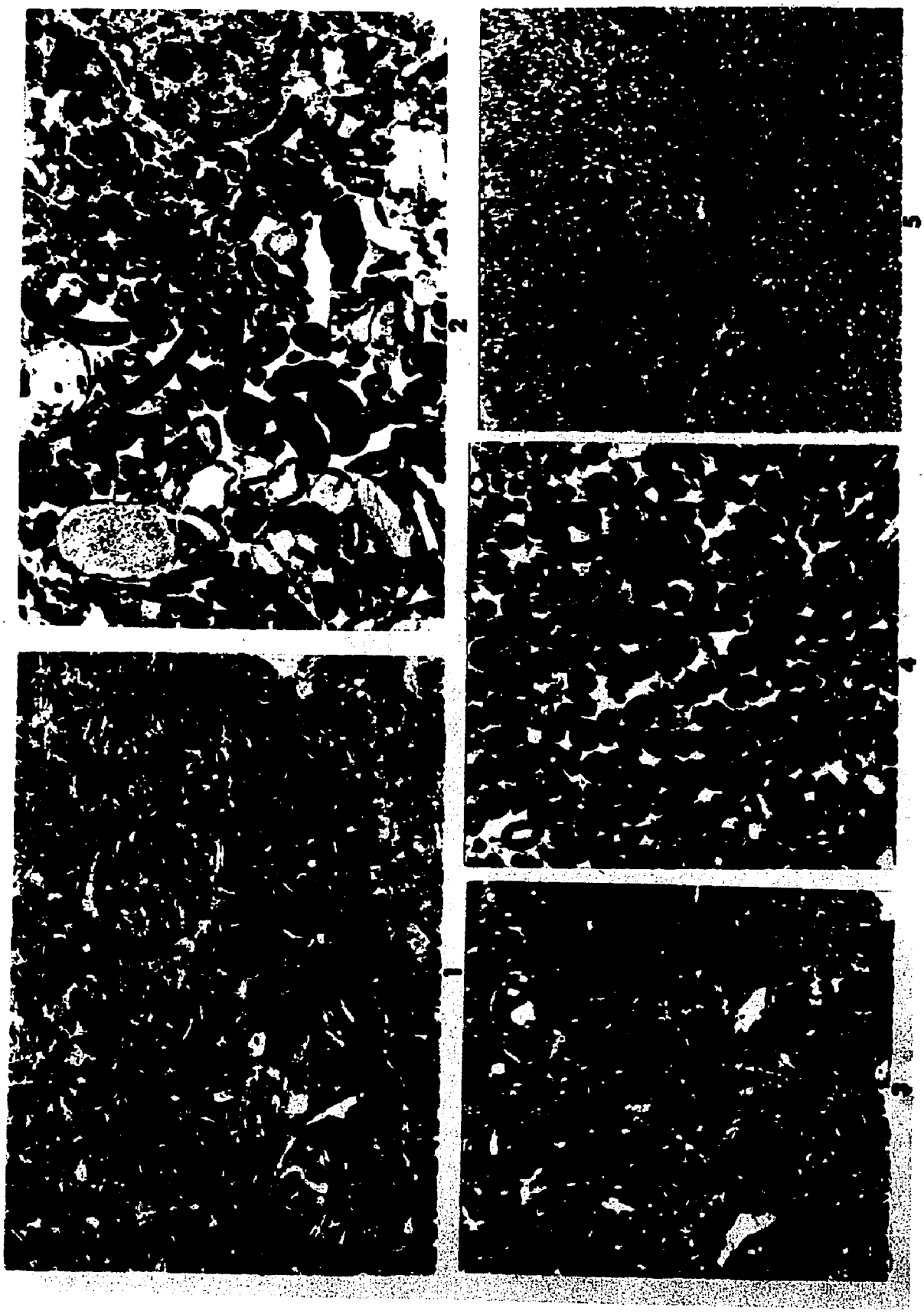


Plate 3

Fig. 1. Minnekahta. Sundance Formation. Canyon Spring Sandstone containing stringers of oyster fragments.

Fig. 2. Minnekahta. Sundance Formation. Oscillation ripples in the Hulett Sandstone.

Fig. 3. Rapid City. Sundance Formation. Ripple-mark sets in the Hulett Sandstone.

Fig. 4. Rapid City. Sundance Formation. Ripple-marks and centrally furrowed trail-marks in the Hulett Sandstone.

PLATE 3

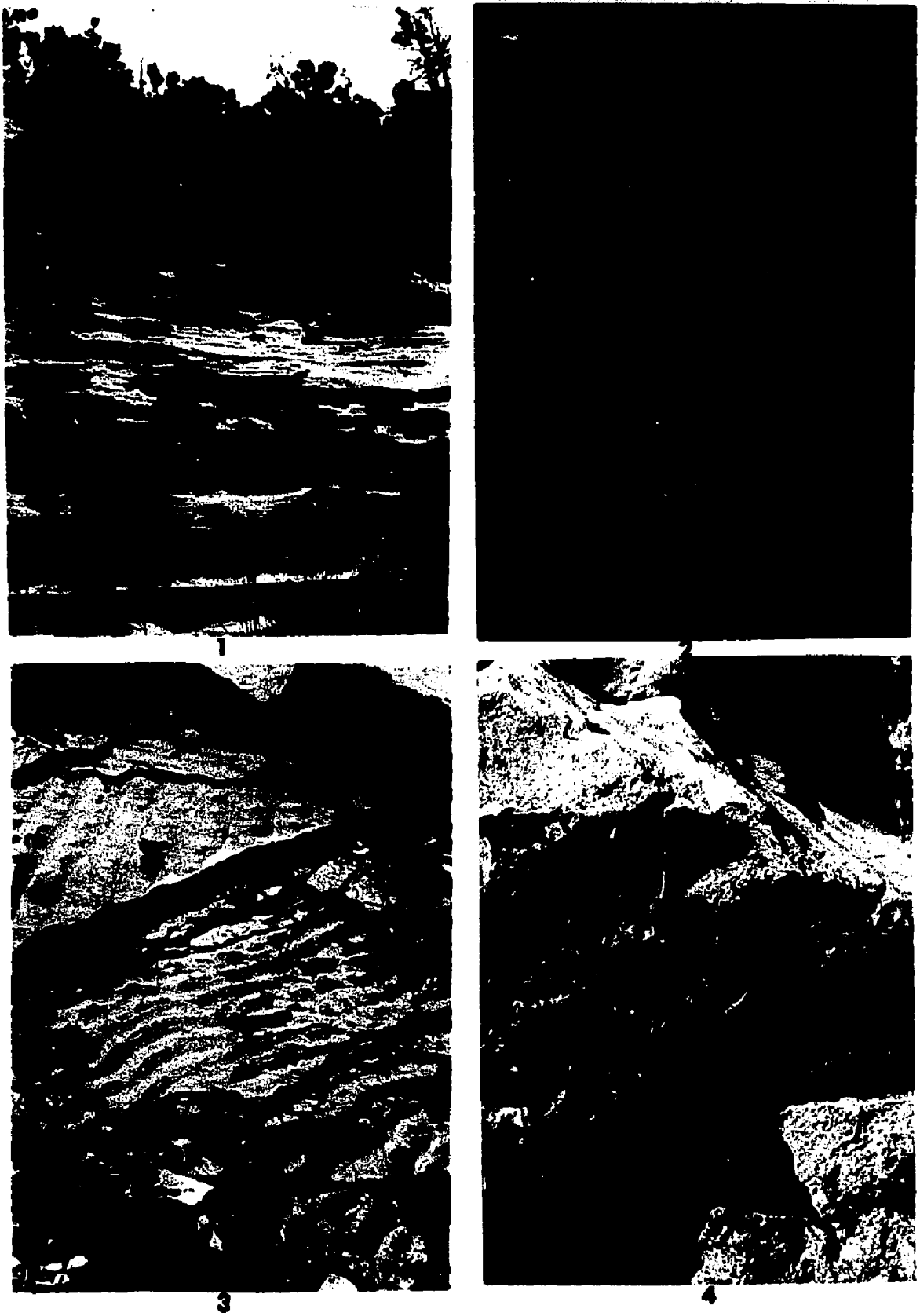


Plate 4

Fig. 1. Douglas. Sundance Formation. Cross-bedding near the base of the Hulett Sandstone.

Fig. 2. Maverick Spring. Sundance Formation. Festoon cross-bedding at the top of the Hulett Sandstone.

Fig. 3. Freezeout Mountains. Sundance Formation. Upper thin-bedded sandstone of the Canyon Springs Sandstone (1), Hulett Sandstone (2), and Lak Member (3).

Fig. 4. Rapid City. Sundance Formation. Hulett Sandstone (1) grading upward into the Lak Member (2).

PLATE 4

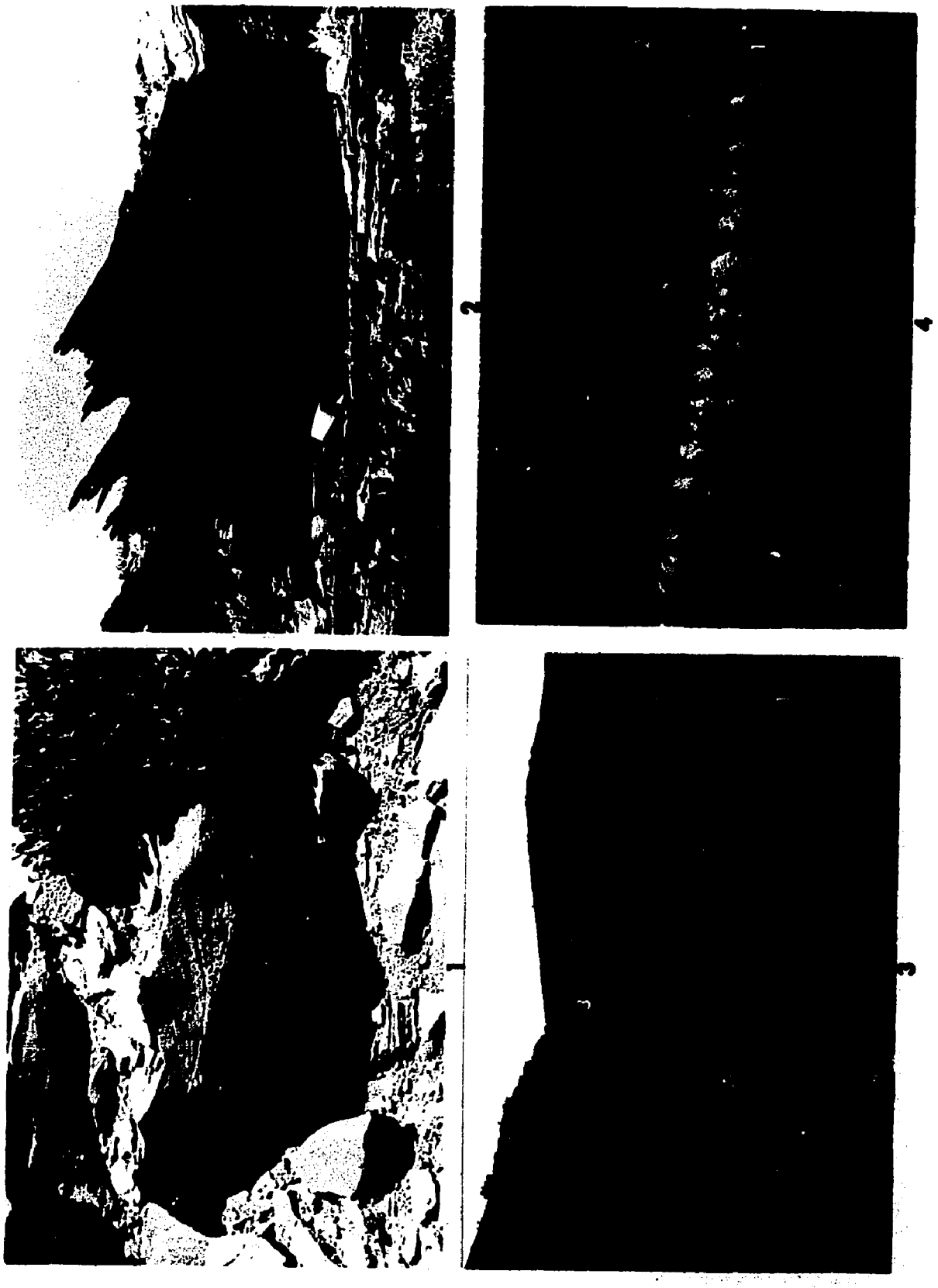


Plate 5

Fig. 1. Freezeout Mountains. Sundance Formation. Cross-beds in the upper part of the Lak Member.

Fig. 2. Freezeout Mountains. Sundance Formation. White nonresistant sandstone of the Lak Member.

Fig. 3. Thermopolis. Entire exposure of the "Upper Sundance."

Fig. 4. Thermopolis. Sandstone covered with Camptonectes bellistriatus. "Upper Sundance."

PLATE 5

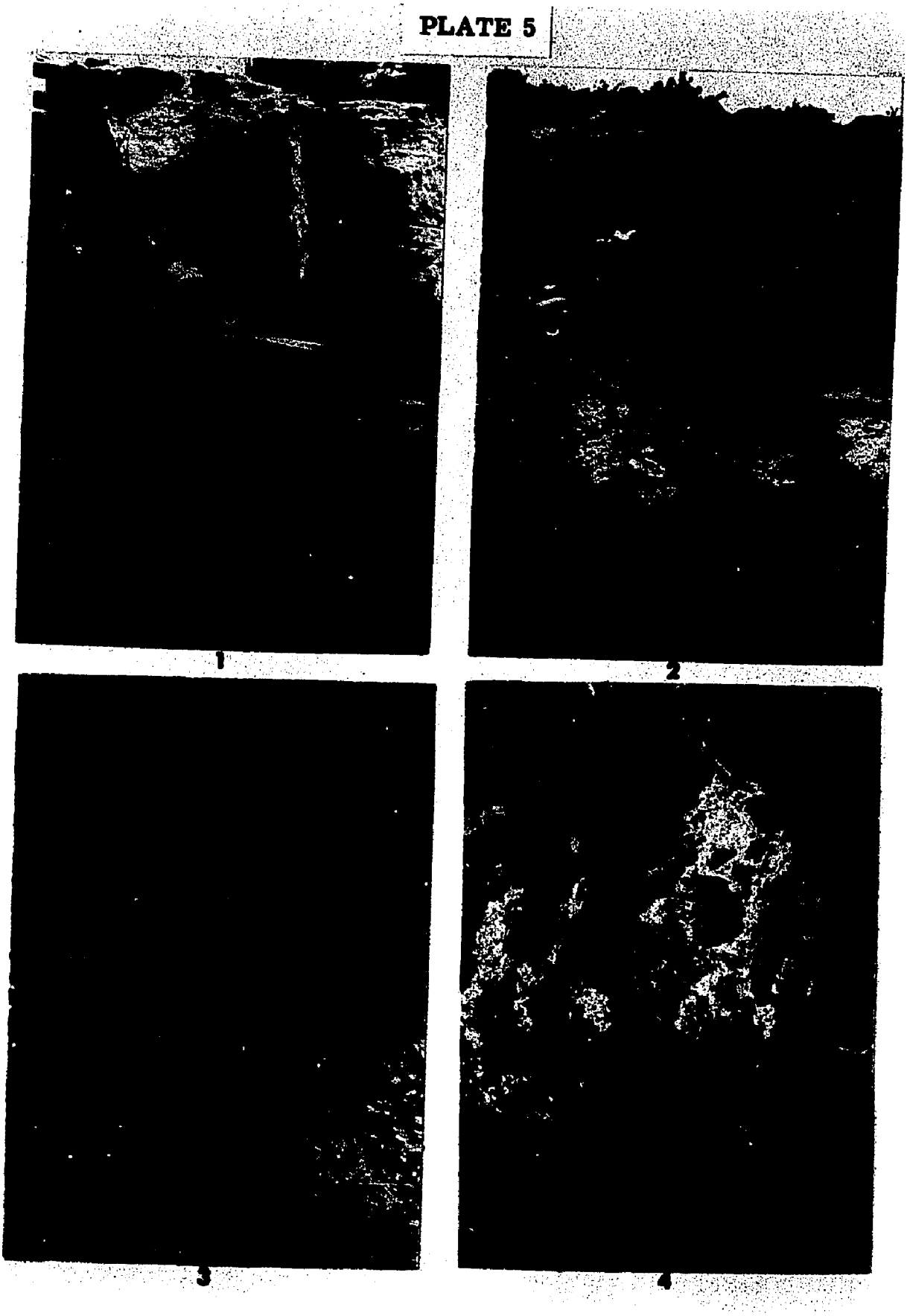


Plate 6

Fig. 1. Freezeout Mountains. Sundance Formation. Cross-bedding in the Pine Butte Member.

Fig. 2. Bull Lake. Sundance Formation showing the predominance of sandstone making up the Redwater Shale (3). Stockade Beaver Shale (1), and Hulett Sandstone (2).

Fig. 3. Douglas. Sundance Formation. Limestone (biosparite) packed with bivalve shells at the top of the Redwater Shale.

Fig. 4. Alcova. Sundance Formation. Limestone beds containing Camptonectes bellistriatus, Redwater Shale.

PLATE 6

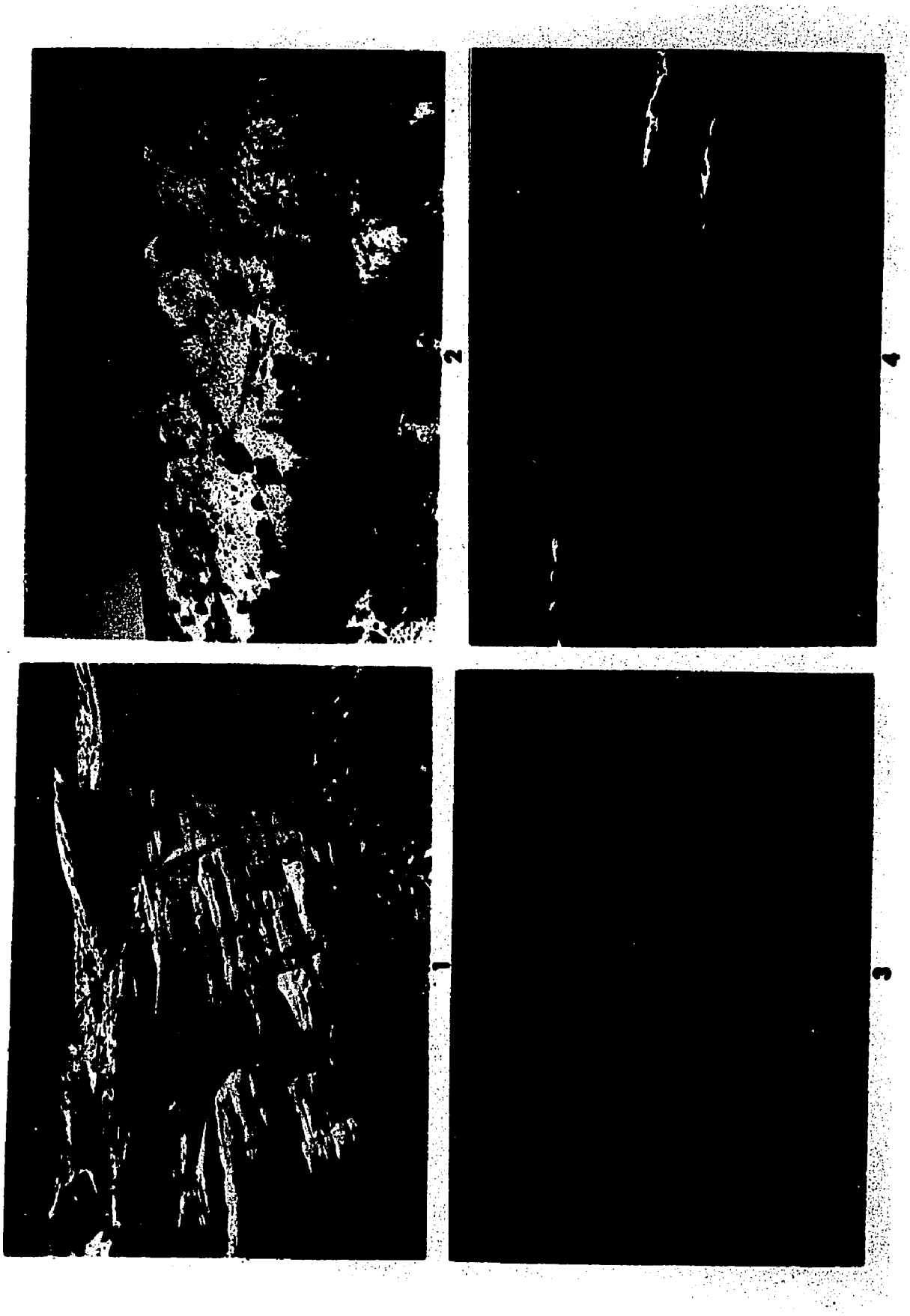


Plate 7

Fig. 1. Vinceants. Sundance Formation. Bored surface near the bottom of the Stockade Beaver Shale.

Fig. 2. Alcova. Sundance Formation. Redwater Shale with limestone beds packed with valves of Camptonectes bellistriatus. The vertically disposed valves represent a death position due to current movement or opening of valves after death.

Fig. 3. Vinceants. Sundance Formation. Limestone beds in the Redwater Shale.

Fig. 4. Maverick Spring. Sundance Formation. Festoon cross-beds at the top of the Hulett Sandstone.

PLATE 7

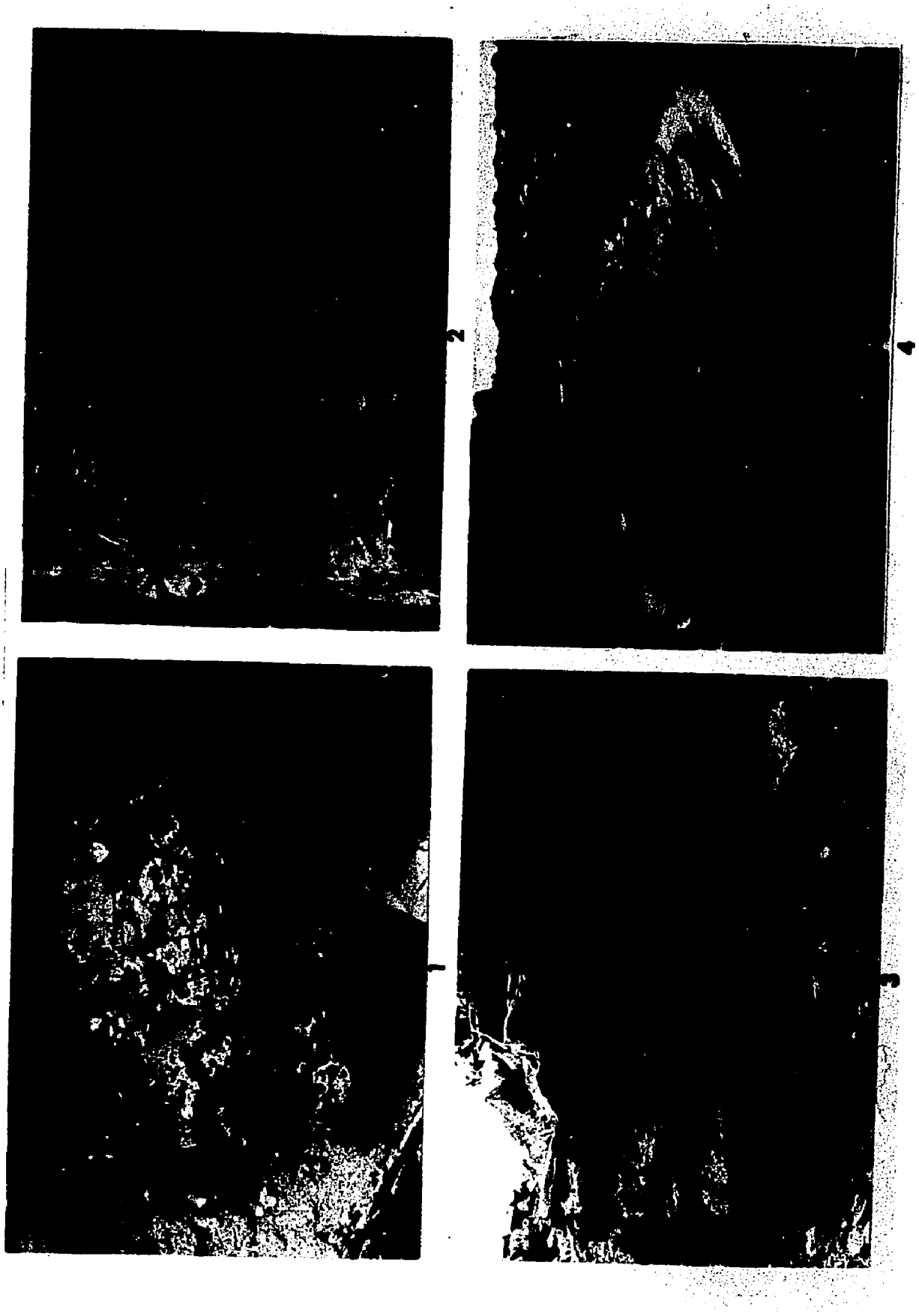


Plate 8

Fig. 1. Calcareous fossiliferous glauconitic sandstone. Fossil fragments include oysters and a few echinoderm and ostracod fragments. 5X
Redwater Shale of the Sundance Formation. Newcastle.

Fig. 2. Poorly washed biosparite. Allochems include bivalve fragments. 5X
Redwater Shale of the Sundance Formation. Alcova.

Fig. 3. Sandy biomicrite. 5X
Redwater Shale of the Sundance Formation. Alcova.

Fig. 4. Sandy biosparite. 5X
Redwater Shale of the Sundance Formation. Vinceants.

PLATE 8

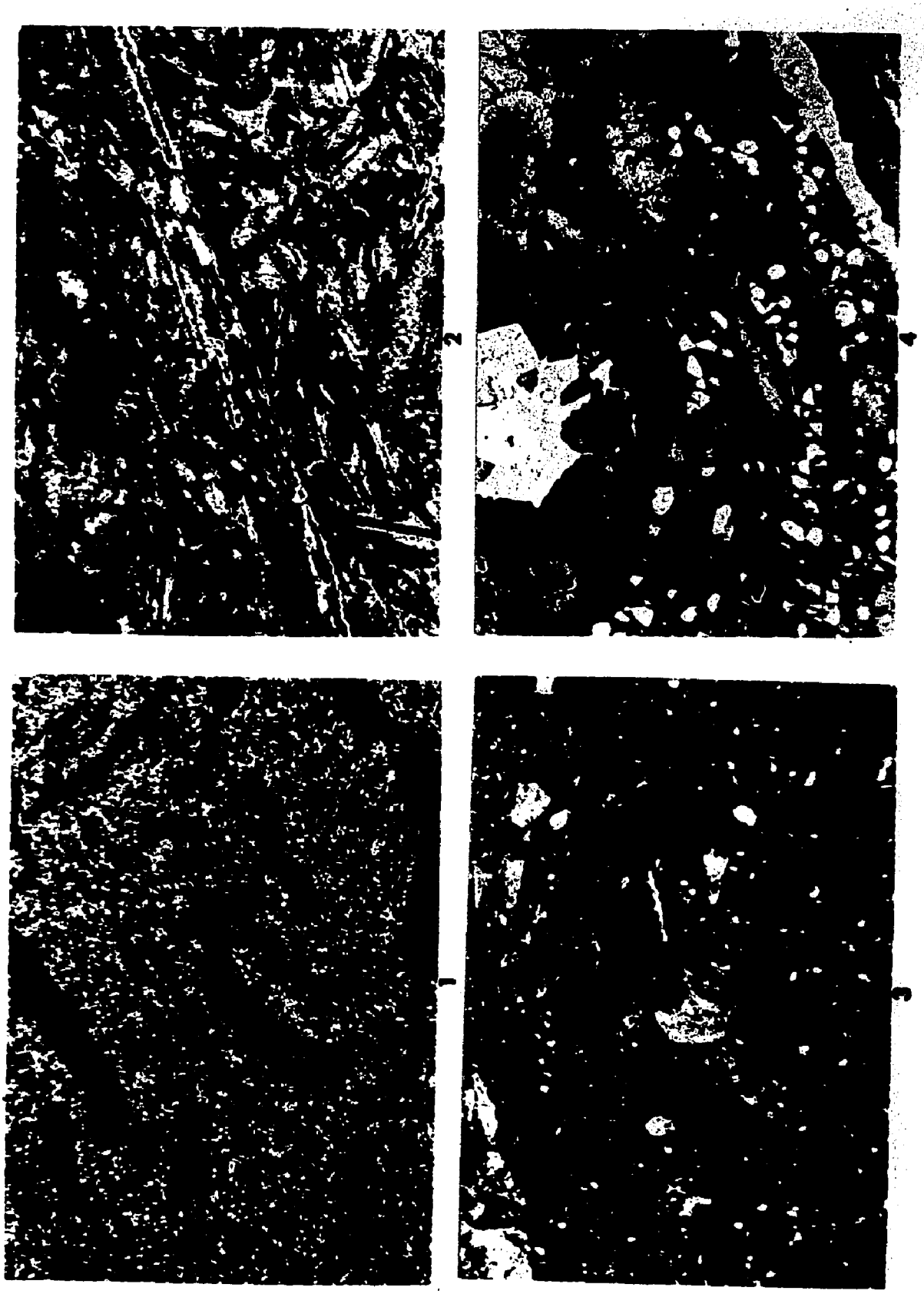


Plate 9

Fig. 1. Seminoe Dam. Sundance Formation. Cross-bedding in the Windy Hill Sandstone.

Fig. 2. Alcova. Sundance Formation. Ripple-marked Windy Hill Sandstone (2) overlying the top of the Redwater Shale (1).

Fig. 3. Thermopolis. Lower sandstone member of the "Lower Sundance."

Fig. 4. Thermopolis. Sundance Formation. Middle shale member (1) and upper sandstone member (2) of the "Lower Sundance." The lower shale member (3) and upper sandstone member (4) of the "Upper Sundance."

PLATE 9

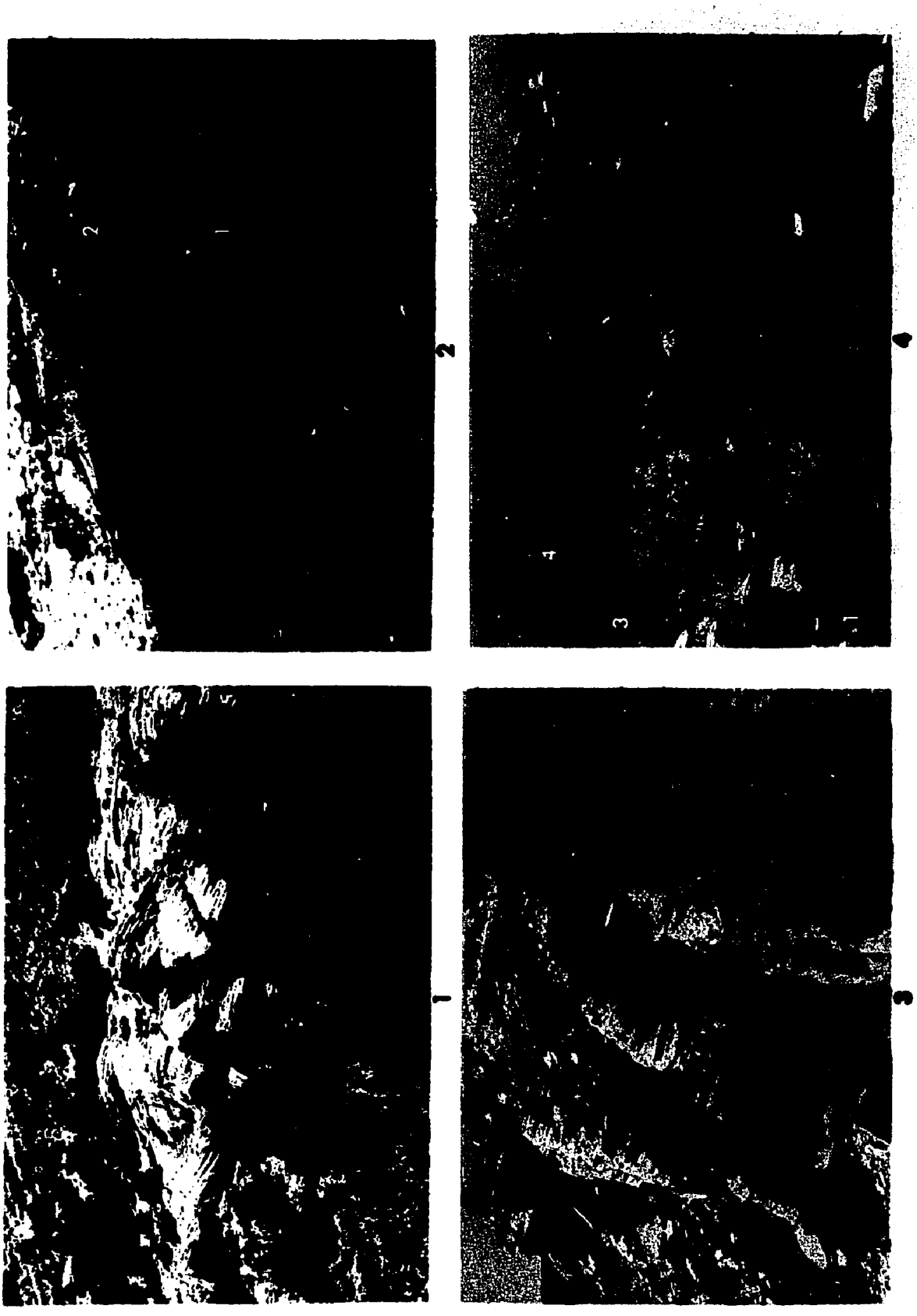


Plate 10

Fig. 1. Lovell. Gryphaea nebrascences covering exposed bedding planes of the middle shale member of the "Lower Sundance."

Fig. 2. Thermopolis. Thin-bedded ripple-marked sandstone in the upper sandstone member of the "Lower Sundance."

Fig. 3. Thermopolis. Ripple-marked sandstone in the upper sandstone member of the "Lower Sundance."

Fig. 4. Cody. Sandstone beds containing Tancredia sp. near the base of the "Upper Sundance."

PLATE 10

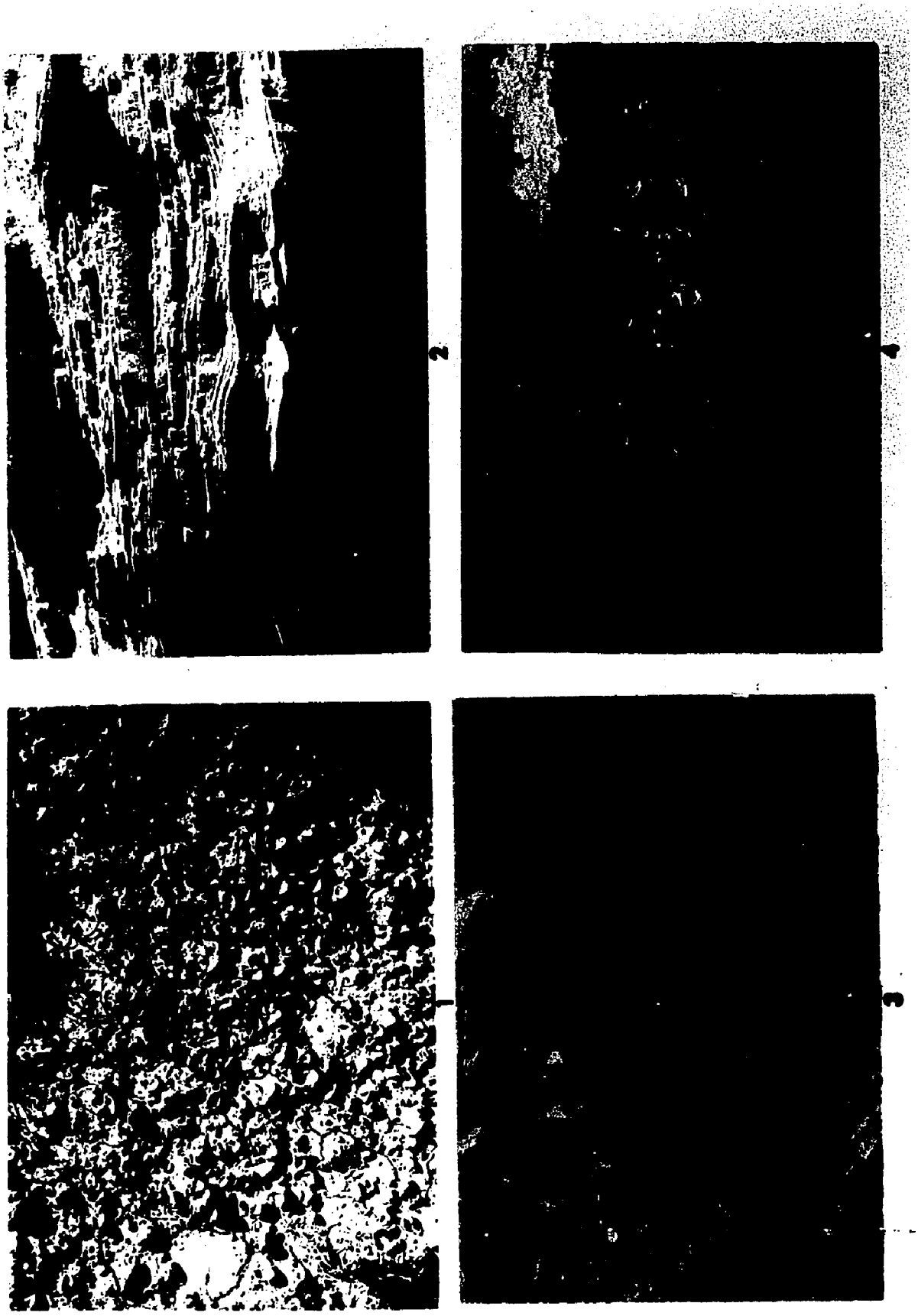


Plate 11

Fig. 1. Sandy oosparite. 5X
Lower sandstone member of the "Lower Sundance."
Thermopolis.

Fig. 2. Sandy oosparite. 5X
Upper sandstone member of the "Lower Sundance."
Thermopolis.

Fig. 3. Oobiosparite cut by oolitic sandstone. Oobiosparite contains oolites, bivalve fragments, pellets, and intraclasts.
Upper sandstone member of the "Lower Sundance."
Tensleep. 5X

Fig. 4. Oosparite. 5X
Oolites with fine-grained quartz sand cemented by calcite.
Sliderock Member of the Twin Creek Limestone.
Ditch Creek.

PLATE 11

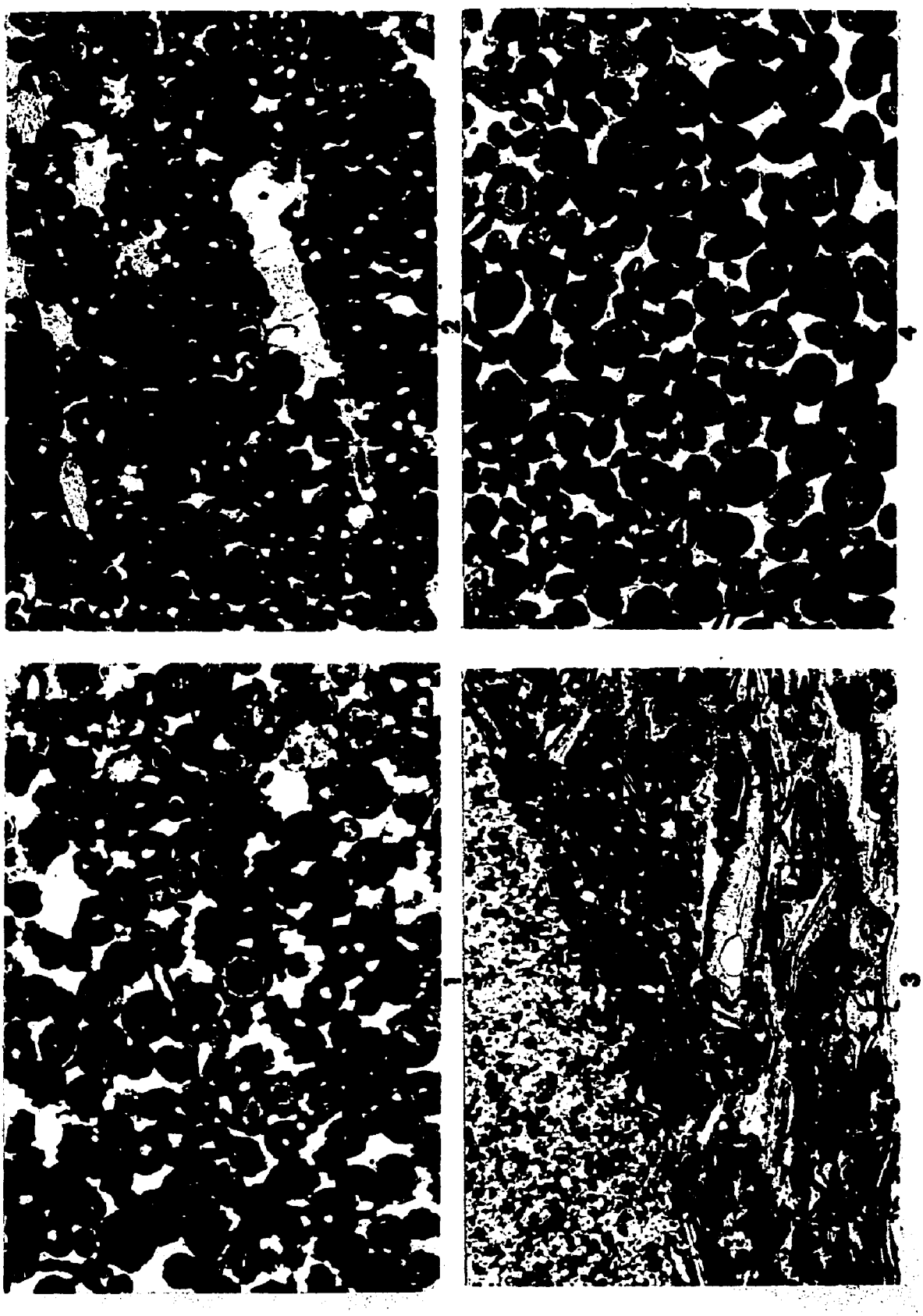


Plate 12

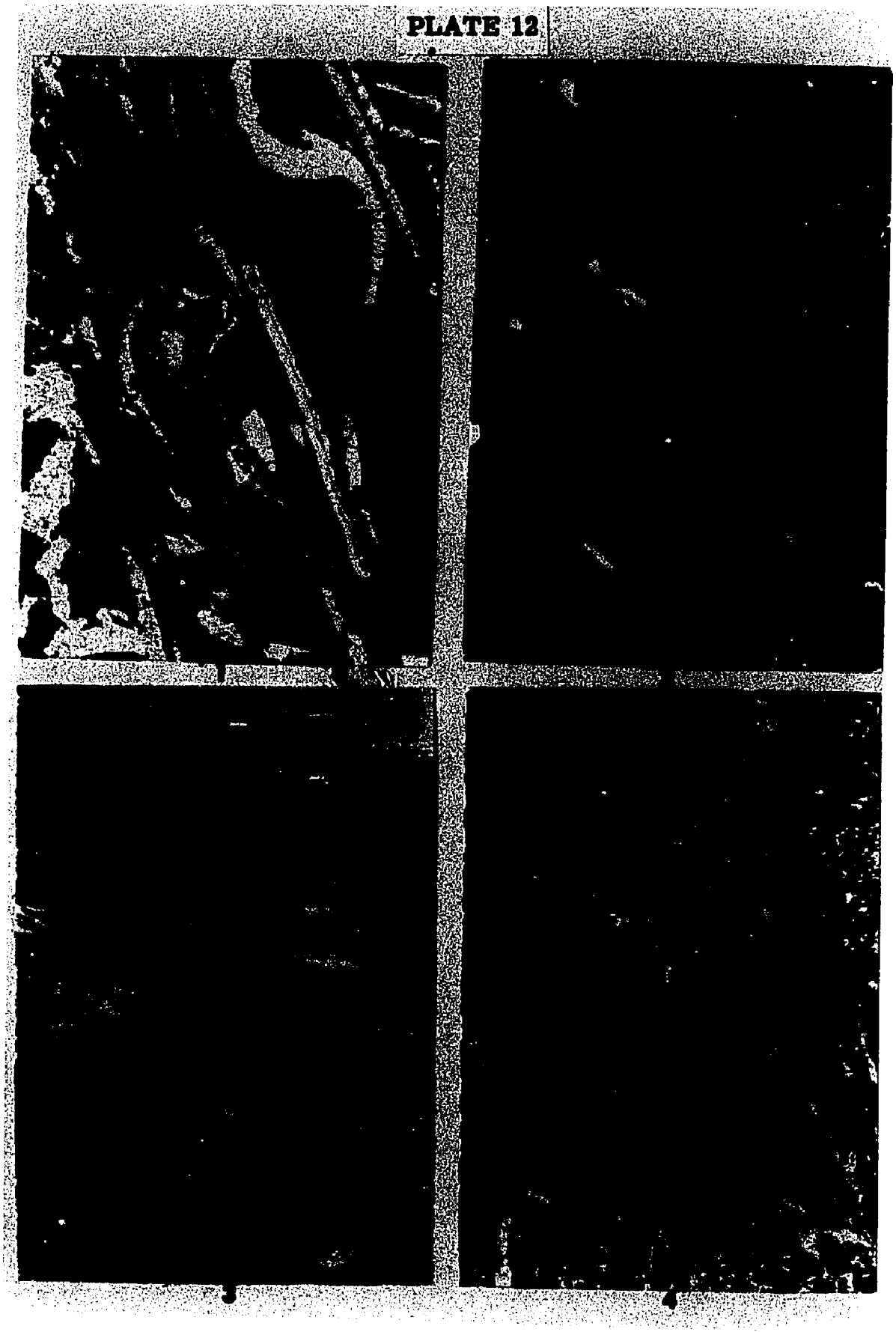
Fig. 1. Sandy biomicrite. Allochems include bivalve and echinoderm fragments and oolites. Quartz stringers common. 5X
Leeds Creek Member of the Twin Creek Limestone.
Cabin Creek.

Fig. 2. Fossiliferous micrite. Bivalve and echinoderm fragments. 5X
Rich Member of the Twin Creek Limestone.
Cabin Creek.

Fig. 3. Freezeout Mountains. Sundance Formation.
Windy Hill Sandstone.

Fig. 4. Poorly washed sandy biosparite. Allochems include bivalve and echinoderm fragments, foraminifera, pellets, and intraclasts.
Note sand filled burrows. 5X
Boundary Ridge Member of the Twin Creek Limestone.
Cabin Creek.

PLATE 12



APPENDIX B

Stratigraphic Sections

(Sections given where bivalves were collected. Collecting horizons given at left of lithology. Refer to appendix C for list of bivalves.)

Buffalo Gap

		Ft.	In.
Sundance Formation			
Hulett Sandstone			
	Shale, salmon-gray, soft, calcareous, overlain by red siltstone of Lak Member	1	8
	Sandstone, greenish-gray, calcareous, very fine-grained	0	7
	Shale, greenish-gray, mottled maroon, calcareous	15	0
BG14	Sandstone, light yellowish-gray, calcareous, very fine-grained, glauconitic, slabby, symmetrically ripple-marked, burrowed; interbedded with thin layers of gray shale; bivalves in lower 2 feet	16	5
	Thickness of Hulett Sandstone	33	8
Stockade Beaver Shale			
	Shale, dark-gray; interbeds of yellow sandstone	1	3
BG12	Sandstone, light-gray, calcareous, thin-bedded, very fine-grained, bivalves	0	9
	Shale, dark-gray, sandy, burrowed near top	3	0
	Thickness of Stockade Beaver Shale	5	0
Canyon Springs Sandstone			
	Shale, alternating maroon and gray	15	5
	Sandstone, salmon-red, medium-bedded, fine-grained, soft, cross-bedded	9	0
BG6	Sandstone, yellowish-gray, thin-bedded, calcareous, very fine-grained, friable, burrowed, bivalves	3	6
	Shale, alternating maroon, gray, and green, sandy	5	8
	Sandstone, light-gray to salmon-red, massive, calcareous, very fine-grained, underlain by red shale of Spearfish	4	0
	Thickness of Canyon Springs Sandstone	34	7
	Total thickness of section	73	3

Minnekahta

		Ft.	In.
Sundance Formation			
Hulett Sandstone			
	Sandstone, light-tan, calcareous, medium-grained, medium-bedded	1	8
	Sandstone, light-tan, calcareous, fine-grained, very thin-bedded, shaly	1	3
	Shale, medium-gray to light-tan, sandy	7	6
	Shale, alternating dark-gray and maroon	6	0
	Sandstone, light-tan, calcareous, fine-grained, medium- to thin-bedded, burrowed, symmetrically ripple-marked, cross-bedded	5	0
	Shale, medium-gray	1	8
	Sandstone, white, calcareous, fine-grained, asymmetrically ripple-marked, very small sets of cross-beds, interbeds of gray shale	4	0
	Sandstone, white to salmon-red, calcareous, fine-grained, medium-bedded, symmetrically ripple-marked	8	0
	Thickness of Hulett Sandstone	35	1
Stockade Beaver Shale			
	Shale, dark-gray; interbedded with light-tan medium-grained burrowed sandstone	6	0
M9-12,14,15	Shale, dark-gray, sand stringers with bivalves	32	0
	Shale, maroon-gray	8	0
M6	Siltstone, light-gray, calcareous, sandy, platy, bivalves	1	0
	Sandstone, light-gray, calcareous; limonitic nodules and chert pebbles scattered throughout	0	9
	Sandstone, light-gray, calcareous, thin-bedded, oolitic; packed with oyster shell fragments	1	7
	Thickness of Stockade Beaver Shale	49	4
Canyon Springs Sandstone			
M4	Sandstone, white- to pinkish-gray, calcareous, friable, thin-bedded, fine-grained, thin shale partings; stringers of oyster shells	6	0
	Sandstone, white, medium-bedded; contains red specks and thin limonite bands; underlain by red sandstone of Nugget ?	8	0
	Thickness of Canyon Springs Sandstone	14	0
	Total thickness of section	98	5

Minnekahta

		Ft.	In.
Sundance Formation			
Hulett Sandstone			
	Sandstone, light-tan, calcareous, fine-grained, thin-bedded, symmetrically ripple-marked...	5	0
	Sandstone, light-tan, calcareous, fine-grained, bedding platy, symmetrically ripple-marked; interbedded with paper-thin dark gray shale...	4	0
	Sandstone, light-tan, calcareous, fine-grained, medium-bedded, symmetrically ripple-marked, burrowed.....	3	0
	Thickness of Hulett Sandstone.....	12	0
Stockade Beaver Shale			
M7,8	Shale, dark-gray, slightly calcareous; interbedded with thin beds of fine-grained, calcareous, burrowed, light-tan sandstone; bivalves..	12	0
M5,6	Shale, medium-gray, calcareous, bivalves.....	9	5
M4	Sandstone, light-olive-gray, very fine-grained, calcareous, hard; bivalves, echinoderm fragments.....	0	3
M3	Shale, medium-gray, calcareous; bivalves.....	14	3
	Thickness of Stockade Beaver Shale...	35	11
Canyon Springs Sandstone			
	Sandstone, white, calcareous, coarse-grained, medium-bedded; more resistant than underlying sandstone.....	2	0
	Sandstone, white, calcareous, fine-grained, medium-bedded; underlain by red sandstone of Nugget Sandstone?.....	10	0
	Thickness of Canyon Springs Sandstone.....	12	0
	Total thickness of section.....	59	11

Rapid City

		Ft.	In.
Sundance Formation			
Hulett Sandstone			
	Siltstone, light-tan, platy; overlain by red siltstone of Lak Member.....	0	7
	Shale, light-gray.....	3	3
RC26	Shale, light-gray; interbedded with thin-bedded, very fine-grained, grayish-orange calcareous, rippled, and trailed sandstone; bivalves near base.....	6	7
	Shale, greenish-gray and maroon beds, alternate..	1	3

		Ft.	In.
RC22,23	Sandstone, pale yellowish-orange, calcareous, fine-grained, interference ripple-marked, burrowed, thin-bedded to medium-bedded; brachiopods	15	10
	Thickness of Hulett Sandstone	27	6
	Stockade Beaver Shale		
RC20	Sandstone and shale, pale yellowish-orange, calcareous, very fine-grained, slightly friable, symmetrically ripple-marked, medium to thin-bedded, burrowed, cross-bedded; sandstone interbedded with gray and maroon shale beds from one inch to one foot thick; bivalves 12 feet above base	15	0
	Shale, color variable from gray and maroon to greenish-gray	8	0
	Sandstone, pinkish-orange, calcareous, very fine-grained	0	3
	Siltstone, greenish-brown	0	10
	Sandstone, reddish-brown, calcareous, fine-grained, medium-bedded	1	3
	Sandstone, pinkish-white, calcareous, fine-grained, medium-bedded	1	5
	Siltstone, maroon, calcareous, thin-bedded	0	6
	Shale, maroon gray and grayish-green beds alternate; shale alternates with white and yellowish-brown calcareous fine-grained thin-bedded symmetrically ripple-marked burrowed sandstone and maroon siltstone	13	0
RC5	Sandstone, pale reddish-brown, very fine-grained, calcareous, silty, burrowed; bivalves	0	3
	Shale, maroon	0	5
	Shale, medium-gray	5	5
	Shale, maroon, calcareous, silty	0	7
	Shale, medium-gray	6	0
RC3	Siltstone, moderate yellowish-brown, very calcareous, slightly-rippled, burrowed, bivalves	0	2
	Shale, medium-gray	5	5
	Sandstone, yellowish-brown, calcareous, fine-grained	0	1
	Shale, dark-gray, maroon near the base	5	3
	Thickness of Stockade Beaver Shale	63	10
	Canyon Springs Sandstone		
	Sandstone, yellow, calcareous, fine-grained; fractured and fractures full of vein quartz; underlain by red siltstone of Spearfish Formation	1	5

	Ft.	In.
Total thickness of section	92	9

Douglas

Sundance Formation

Redwater Shale

D38	Limestone, light olive-gray, packed sandy biosparite, glauconitic, thin-bedded, ripple-marked; packed with bivalve shell fragments; overlain by variegated shale of Morrison.....	3	0
	Sandstone, white, calcareous, friable, fine-grained, glauconitic, platy.....	1	0
	Sandstone, greenish-gray, calcareous, very fine-grained, glauconitic; cross-bedded throughout; bivalve fragments.....	2	0
	Shale, dark-gray, soft, sandy in spots, lime nodules (cobbles).....	12	0
	Limestone, dark-gray, micrite.....	0	10
	Shale, dark-gray, soft; belemnites and ammonites in lower 8 feet.....	26	8
	Sandstone, light brownish-gray, calcareous, fine-grained, thin-bedded, trail-marked, interbeds of gray shale.....	3	3
	Shale, medium-gray, sandy, belemnites.....	6	10
	Thickness of Redwater Shale.....	54	9

Pine Butte Member

	Sandstone, dark-brown, calcareous, medium-bedded, thin-bedded, burrowed and trail-marked.....	1	3
	Sandstone, light-brown, very calcareous, glauconitic, medium-grained, massive bedded; thin-bedded at the base.....	12	0
D26	Limestone, light olive-gray, sandy oobiosparite, medium-bedded, hard; bivalve, gastropod, and echinoderm fragments.....	2	0
	Shale, medium-gray, soft, sandy.....	12	8
	Siltstone, medium-gray, very thin-bedded; underlain by hard brownish-red fine-grained sandstone.....	0	8
	Shale, varicolored medium-gray to light-green, soft.....	16	0
	Sandstone, light-gray, calcareous, medium-grained, thin-bedded, hard; cross-bedded throughout.....	3	0
	Thickness of Pine Butte Member.....	47	7

Lak Member

	Shale, light maroonish-tan, very sandy, slightly gypsiferous, calcareous.....	22	2

		Ft.	In.
	Sandstone, light-tan, calcareous, medium-grained, thin-bedded, shaly	7	0
	Siltstone, light gray-tan, soft, sandy	12	0
	Thickness of Lak Member	41	0
	Hulett Sandstone		
D-10-			
12	Sandstone, white to yellowish-gray, calcareous, very fine to fine-grained, thin to medium-bedded, symmetrically ripple-marked; very fine cross-bedding common throughout; bivalves	18	8
	Thickness of Hulett Sandstone	18	8
	Stockade Beaver Shale		
	Shale, dark-gray, soft; interbedded burrowed thin sandstone beds common	13	6
	Shale, medium-gray, very sandy	5	8
	Limestone, medium-gray, granular, sandy, burrowed	0	3
D4	Shale, light olive-gray, calcareous, silty and sandy; bivalves	10	2
	Thickness of Stockade Beaver Shale	27	7
	Canyon Springs Sandstone		
D2	Sandstone, white calcareous, medium-grained, massive-bedded	13	0
	Sandstone, white, calcareous, medium-grained, thin-bedded	3	10
	Sandstone, white, medium-grained, cross-bedded throughout; underlain by Jelm Formation?	50	0
	Thickness of Canyon Springs Sandstone	66	10

Lander

		Ft.	In.
	Sundance Formation		
	Windy Hill Sandstone		
	Sandstone, light tan, calcareous, medium-grained, thin-bedded at base, medium-bedded in upper part; overlain by sandstone of the Morrison	10	6
	Redwater Shale		
	Sandstone, medium grayish-green, calcareous, slightly glauconitic, calcareous, shaly, soft	26	0
	Limestone, medium grayish-green, sandy, blocky	1	0
	Sandstone, medium grayish-green, medium-grained, calcareous, glauconitic, thin-bedded, ripple-marked, cross-bedded	17	3

		Ft.	In.
L29	Limestone, light brownish-gray; poorly washed, fragmented, arenaceous biomicrite and sparite; glauconitic, medium-bedded; packed with bivalve shells, echinoderm fragments, and angular quartz	1	3
	Sandstone, brownish-gray, medium-grained, calcareous, thin-bedded	6	4
	Sandstone, grayish-brown, calcareous, very glauconitic, medium-bedded; cross-bedded in spots	19	0
L25	Limestone, light brownish-gray, biomicrite; sandy and cherty, glauconitic, bivalve and echinoderm fragments, medium-bedded; bivalves	3	0
L23,24	Sandstone, light-gray, calcareous, glauconitic, fine-grained, medium-bedded; interbedded with very glauconitic, soft sandstone; full of oyster fragments, some echinoderm fragments	2	3
	Siltstone, brownish-gray, calcareous, sandy, soft, thin-bedded	6	0
	Shale, medium-gray, soft	1	3
L21	Siltstone, light olive-gray, very calcareous, slightly glauconitic; medium-bedded, packed with bivalves	0	8
	Shale, medium-gray, soft	10	0
	Siltstone, light brownish-gray, calcareous, sandy, thin-bedded	12	0
	Shale, dark-gray, soft	6	3
L16	Claystone, yellowish-gray, very calcareous, sandy and slightly glauconitic; a few chert pebbles occur throughout; bivalves	2	3
L15	Limestone, light-gray, arenaceous, oosparite slightly glauconitic, thin-bedded; with intraclasts, bivalve and echinoderm fragments, chert fragments; bivalves	3	0
	Shale, dark-gray, silty, very glauconitic	5	3
	Thickness of Redwater Shale	123	9
Lak Member			
	Siltstone, light-red, calcareous, soft	1	2
	Sandstone, white, calcareous, medium-grained, medium-bedded	1	0
	Siltstone, light-red, calcareous, soft	1	8
	Sandstone, white, calcareous, medium-grained, soft, thin-bedded	1	8
	Siltstone, light-red, calcareous, soft	12	8
	Thickness of Lak Member	18	2

	Ft.	In.
Hulett Sandstone		
Shale, grayish-green, calcareous, soft.....	10	0
Sandstone, tan, calcareous, medium-grained, soft, medium-bedded; cross-bedded throughout.....	4	0
Thickness of Hulett Sandstone.....	12	0
Stockade Beaver Shale		
Shale, medium-gray, slightly calcareous, soft; a few chert pebbles near base.....	15	0
Sandstone, medium-brown, calcareous, oolitic, fine-grained.....	1	3
L3 Claystone, very light-gray, very calcareous, soft; bivalves.....	3	10
Limestone, light grayish-brown, sandy, hard, platy; bivalve and gastropod fragments; trail marked.....	10	4
L1 Claystone, very light-gray, calcareous, slightly silty, soft; bivalves; overlying gray limestone and reddish-brown claystone of gypsum.	2	0
Thickness of Stockade Beaver Shale...	32	5
Total thickness of section.....	196	4

Vinceant Ranch

	Ft.	In.
Sundance Formation		
Redwater Shale		
V38 Limestone, yellowish-gray, crystalline, sandy, glauconitic, medium-bedded; packed with bivalves; overlain by Windy Hill Sandstone (not measured).....	3	10
Sandstone, greenish-gray, calcareous, medium-grained, glauconitic, thin-bedded, soft; cross-bedded in lower 4 feet.....	9	6
V36 Sandstone, light olive-gray, calcareous, fine to very fine-grained, glauconitic, thin-bedded; bivalves.....	1	0
V35 Limestone, light-gray, thin-bedded; bivalves.....	2	3
Siltstone, greenish-gray, sandy.....	1	8
V34 Sandstone, light olive-gray, calcareous, very fine-grained, glauconitic, bedding flaggy, ripple-marked; oyster shells.....	2	3
Siltstone, greenish-gray, very sandy, glauconitic..	4	10
V33 Limestone, light-gray, thin-bedded; packed with bivalve fragments.....	0	3
Siltstone, greenish-gray, soft, glauconitic.....	3	6

		Ft.	In.
V32	Limestone, light olive-gray, biosparite, glauconitic, blocky; packed with bivalve fragments.	5	2
V30	Sandstone, light olive-gray, very fine-grained, glauconitic, soft, medium-bedded; burrowed throughout; bivalves	2	0
	Shale, medium-gray, soft	16	0
V27	Sandstone, light olive-gray, very fine-grained, glauconitic, thin-bedded; bivalves	0	9
	Shale, light greenish-gray, soft	5	0
V26	Sandstone, light olive-gray, very fine-grained, glauconitic, thin-bedded; bivalves	0	10
	Shale, medium-gray, soft	8	0
	Siltstone, grayish-green, soft, glauconitic; burrowed in lower 5 feet	13	3
V22	Sandstone, light olive-gray, very fine-grained, glauconitic, thin-bedded, burrowed; bivalves.	0	10
	Siltstone, greenish-gray, soft, glauconitic	10	5
V20	Limestone, light brownish-gray, sandy oobiomicrite, glauconitic, medium-bedded; with bivalve, echinoderm, and belemnite fragments and intraclasts	2	0
V19	Siltstone, light olive-gray, glauconitic, soft, bivalves in upper foot, belemnites	20	0
	Shale, medium-gray, soft; belemnites	11	0
	Thickness of Redwater Shale	113	4
Lak Member			
	Sandstone, light-yellow, slightly calcareous, medium-grained, soft, thin-bedded, extensively burrowed with burrows branching and being up to 1 foot long	1	3
	Siltstone, maroon and gray, soft	5	0
	Sandstone, light yellowish-tan, medium-grained, thick-bedded	2	5
	Siltstone, maroon, sandy, hard	2	8
	Sandstone, light yellowish-tan, medium-grained, soft, medium-bedded; interbedded with maroon siltstone	2	0
	Siltstone, maroon, soft	28	8
	Thickness of Lak Member	42	0
Hulett Sandstone			
	Shale, light-gray, silty, soft; interbedded with light-brown medium-grained thin-bedded ripple-marked sandstone in lower 5 feet	14	0
Stockade Beaver Shale			
	Siltstone, brownish-gray, soft	6	0
	Shale, brownish-gray, soft	10	6

	Ft.	In.
Limestone, gray-tan; top surface bored, gastropod fragments, chert pebbles in the middle of unit; underlain by reddish-brown claystone of Gypsum Spring Formation.....	4	8
Thickness of Stockade Beaver Shale..	20	8
Total thickness of section.....	189	0

Seminoe Dam

Sundance Formation	Ft.	In.
Windy Hill Sandstone		
Sandstone, white, very calcareous, medium-grained, very oolitic, thin-bedded; festoon cross-bedded in upper part; overlying slope partially covered by sandstone of Morrison Formation.....	50+	0
Redwater Shale		
Limestone, light-gray, crystalline, oolitic, medium-bedded; tops of beds are symmetrically rippled.....	4	3
Shale, dark greenish-gray, slightly calcareous, soft.....	7	3
SD24 Sandstone, olive-gray, very fine-grained, very calcareous, glauconitic, medium-bedded and blocky, slightly cross-bedded; bivalves..	3	2
Sandstone, medium-brown, very fine-grained, calcareous, slabby, very silty; soft and form shallow slopes.....	8	0
Shale, medium-brown, silty, soft.....	4	8
SD22,23 Limestone, light olive-gray, crystalline, slightly glauconitic, blocky; bivalves.....	6	10
Shale, medium-gray, soft, calcareous, silty in lower 8 feet; belemnites occur throughout....	47	0
Siltstone, light greenish-gray, calcareous, sandy, soft; belemnites occur throughout.....	17	0
Thickness of Redwater Shale.....	98	2
Lak Member		
Siltstone, salmon-red, soft, calcareous.....	18	0
Hulett Sandstone		
Sandstone, white, calcareous, very fine-grained, thin-bedded; cross-bedded in lower 24 feet; unit forms a resistant ledge.....	39	0
Sandstone, white, calcareous, very-fine-grained, shaly, forms non-resistant slope.....	18	0
Limestone, light-pink, crystalline.....	1	0
Thickness of Hulett Sandstone.....	58	0

	Ft.	In.
Canyon Springs Sandstone		
Sandstone, white, calcareous, medium to fine-grained, medium-bedded; underlain by red siltstone of Nugget Sandstone.....	12	5
Total thickness of section.....	236	5

Bull Lake

Sundance Formation	Ft.	In.
Redwater Shale		
BL28 Sandstone, light olive-gray, very fine-grained, calcareous, glauconitic, medium-bedded; finely cross-bedded; bivalves and brachiopods; overlain by variegated siltstone and shale of the Morrison Formation.....	1	0
Sandstone, greenish-gray, medium-grained, calcareous, glauconitic, soft, thin-bedded....	7	0
Sandstone, light greenish-gray, coarse-grained, salt and pepper texture, very calcareous, medium-bedded.....	5	8
Sandstone, greenish-gray, calcareous, glauconitic, medium-grained, soft, thin-bedded.....	4	8
Sandstone, light greenish-gray, coarse-grained, salt and pepper texture, calcareous.....	0	10
Sandstone, greenish-gray, calcareous, glauconitic, medium-grained, soft, thin-bedded.....	4	10
Sandstone, greenish-gray, coarse-grained, very calcareous, glauconitic, bedding platy, cross-bedded.....	0	8
Siltstone, light greenish-gray, calcareous, sandy, soft.....	2	8
BL26 Sandstone, light greenish-gray, medium to coarse-grained, calcareous, glauconitic; bivalves....	0	8
BL25 Sandstone, yellowish-gray, fine-grained, calcareous, glauconitic, medium-bedded; bivalves.....	6	2
Sandstone, dark greenish-gray, calcareous, glauconitic, silty, soft.....	7	0
BL24 Limestone, medium-gray, sandy; contains belemnite shells; packed with bivalves.....	0	8
Sandstone, greenish-gray, coarse-grained, glauconitic.....	0	3
Siltstone, dark greenish-gray, sandy; contains belemnite shells.....	1	10
Sandstone, light greenish-gray, coarse-grained, salt and pepper texture, calcareous, glauconitic, bedding slabby and cross-bedded.....	2	0

		Ft.	In.
BL23	Limestone, medium-gray, biosparite; packed with bivalves	0	6
	Sandstone, dark greenish-gray, very fine-grained, calcareous, glauconitic, thick to medium-bedded, soft	26	0
	Siltstone, medium-gray, glauconitic, sandy, soft; shaly in lower 10 feet	29	6
BL18	Limestone, medium-gray, glauconitic; full of chert pebbles; bivalves	0	9
	Siltstone, dark greenish-gray, glauconitic, soft	2	3
	Conglomerate, medium brownish-red; full of chert pebbles	1	3
	Shale, dark-gray, calcareous, soft; contain belemnites	24	0
	Thickness of Redwater Shale	130	2
Hulett Sandstone			
	Sandstone, light-tan, calcareous, very fine-grained, thin-bedded, ripple-marked	3	0
	Sandstone, white, calcareous, very fine-grained, medium-bedded; forms rounded ledges	7	0
	Thickness of Hulett Sandstone	10	0
Stockade Beaver Shale			
	Shale, medium greenish-gray, calcareous, soft	6	0
BL12	Sandstone, light-gray, calcareous, very fine-grained; very shaly and forms non-resistant slopes; bivalves 3 feet below top	14	6
BL8-10	Shale, light gray to olive-gray, calcareous, soft, bivalves in middle of unit	36	0
	Limestone pinkish-brown; poorly washed oopel-sparite; bivalve and echinoderm fragments, well sorted quartz grains, blocky	5	6
BL5	Limestone, pale yellowish-brown, sandy bio-pelmicrite, slightly oolitic, bedding platy; bivalves	0	8
	Limestone, light-brown, pelleted, oolitic and sandy, soft	12	0
	Limestone, medium-gray, oolitic, blocky	2	6
	Claystone, light greenish-gray, calcareous, sandy, soft	13	10
	Limestone, medium-gray, poorly washed sandy oosparite, blocky; bivalve and echinoderm fragments, pellets; chert pebbles occur in stringers in lower foot of unit; underlain by reddish-maroon siltstone of Gypsum Spring Formation	2	0

		Ft.	In.
	Thickness of Stockade Beaver Shale...	93	0
	Total thickness of section.....	233	2

Lovell

Sundance Formation
"Upper Sundance"
Upper sandstone member

		Ft.	In.
	Sandstone, light grayish-white, salt and pepper texture, coarse-grained, very calcareous, thin-bedded, beds are commonly ripple-marked; cross bedded in upper 8 feet; overlain by pale-green and pink claystone of Morrison Formation.....	16	0
	Sandstone, yellowish-gray, calcareous, medium to coarse-grained, bedding platy; upper few feet have interference ripple-marks.....	21	0
	Sandstone, yellow, calcareous, fine-grained, bedding-platy; surfaces covered with interference ripple-marks.....	2	0
	Siltstone, yellowish-brown, soft, sandy.....	2	0
	Sandstone, light-gray, calcareous, glauconitic, coarse-grained; bedding platy; salt and pepper texture; oyster-shell fragments scattered on surface of bedding planes.....	5	0
LV23	Sandstone, pale yellowish-brown, calcareous, glauconitic, medium to coarse-grained, bedding platy; bivalves.....	4	0
	Siltstone, light-gray, sandy, soft.....	4	0
	Sandstone, whitish-gray, calcareous, medium to fine-grained; bedding slabby and ripple-marked.....	2	6
	Sandstone, yellowish-brown, fine-grained, hematite stained; bedding platy and symmetrically ripple-marked; alternates with sandy siltstone.....	10	0
	Sandstone, light-brown, medium-grained, salt and pepper texture; bedding platy.....	10	0
	Siltstone, grayish-brown, calcareous, sandy....	3	0
	Sandstone, grayish-brown, coarse-grained, calcareous, salt and pepper texture; bedding platy and slightly ripple-marked.....	5	0
	Sandstone, reddish-brown, calcareous, fine-grained; bedding platy.....	20	0
	Sandstone, medium-brown, calcareous, shaly, soft.....	13	0
	Thickness of upper sandstone member.	117	6

	Ft.	In.
Lower shale member		
LV17 Shale, light-gray, very calcareous, hard; bivalves, bryozoan	0	8
LV15 Shale, light olive-gray, calcareous, soft; belemnites in slope, full of oyster shells in lower 10 feet	32	0
Sandstone, grayish-green, very calcareous, very glauconitic, very fine-grained; shaly, forms non-resistant slope; belemnites and crinoid columnals	7	0
Siltstone, greenish-gray, maroon near base, soft, calcareous, glauconitic; belemnites in slope	31	0
Thickness of lower shale member	70	8
Thickness of "Upper Sundance"	188	2
"Lower Sundance"		
Upper sandstone member		
Limestone, medium-gray, crystalline, thin-bedded, ripple-marked, oolitic; crinoid columnals scattered throughout unit	4	0
Shale, greenish-brown, calcareous, hard; contains 2 resistant shale ledges each 1 foot thick	20	0
Thickness of upper sandstone member	24	0
Middle shale member		
LV4-6, 8 Shale, medium olive-gray, calcareous, soft; bivalves throughout except in upper 5 feet	69	0
Thickness of middle shale member	69	0
Lower sandstone member		
Limestone, light-gray, oolitic	0	2
Shale, light olive-gray, calcareous, soft	5	0
Limestone, medium-gray, oolitic	0	2
Siltstone, light greenish-gray, soft, calcareous	1	10
Limestone, light-gray, oolitic	0	4
Siltstone, light-gray, calcareous, platy	2	0
LV2 Sandstone, very light-gray, oolitic, shaly, burrowed; bivalves	1	8
Siltstone, light-gray, calcareous, platy	2	8
LV1 Limestone, light-gray, oolitic, soft; bench forming; bivalves; underlain by red shale of Gypsum Spring Formation	1	0
Thickness of lower sandstone member	14	10
Thickness of "Lower Sundance"	107	10
Total thickness of Sundance Formation	296	0

Hyattville

Sundance Formation	Ft.	In.
"Upper Sundance"		
Upper sandstone member		
HV21 Sandstone, pale yellowish-brown, medium-grained, glauconitic, very calcareous, medium-bedded; bivalves; overlain by variecolored claystone of Morrison	4	8
Sandstone, whitish-gray, salt and pepper texture, calcareous, thin-bedded, cross-bedded	15	0
HV19 Sandstone, pale yellowish-brown, medium to coarse-grained, glauconitic, very calcareous, medium-bedded; full of oyster fragments; bivalves	1	8
Sandstone, pale yellowish-gray, medium-grained, salt and pepper texture, very glauconitic, calcareous; bedding platy and cross-bedded throughout	14	6
HV17 Sandstone, light-gray, medium-grained, very calcareous, thin-bedded; packed with oyster sheils	2	3
Thickness of upper sandstone member.	38	1
Lower shale member		
Shale, dark-gray, hard; silty in spots	18	0
Siltstone, dark greenish-gray, calcareous, sandy, glauconitic, soft	12	0
Shale, dark greenish-gray, calcareous, soft; oyster-shell fragments on slope	36	0
HV10 Siltstone, light olive-gray, very calcareous, thin-bedded; packed with bivalve shells	1	10
Shale, dark-gray, calcareous, soft; oyster shells on slope	22	0
Thickness of lower shale member	89	10
Thickness of "Upper Sundance"	127	11
"Lower Sundance"		
Upper sandstone member		
Siltstone, salmon-red, soft, gypsiferous	8	0
Shale, dark-gray, calcareous, soft	7	0
Sandstone, white, very fine-grained, calcareous; silty and forms non-resistant slopes	15	0
Thickness of upper sandstone member.	30	0
Middle shale member		
Shale, greenish-gray, calcareous, soft	15	0

		Ft.	In.
Lower sandstone member			
	Sandstone, gray, oolitic; underlain by red shale of Gypsum Spring Formation.....	0	2
	Thickness of "Lower Sundance".....	45	2
	Total thickness of Sundance Formation.	173	1

Tensleep

Sundance Formation			
"Upper Sundance"			
Upper sandstone member			
T23	Sandstone, very light-gray, glauconitic, calcareous, medium-bedded; surface covered with bivalve molds; overlain by gray silty claystone of Morrison Formation.....	5	0
	Sandstone, greenish-gray, medium-grained, calcareous, very glauconitic, bedding platy and finely cross-bedded throughout.....	15	0
TS22	Sandstone, medium-gray, salt and pepper texture, medium-grained, glauconitic, medium-bedded; full of oyster shells and bivalve molds.....	3	6
	Sandstone, medium-gray, salt and pepper texture, medium-grained; bedding platy, cross-bedded, and interference ripple-marked; occasional oyster-shells.....	1	6
	Sandstone, gray, very fine-grained, calcareous, glauconitic, thick-bedded and blocky.....	4	0
	Thickness of upper sandstone member.	28	0
Lower shale member			
	Shale, dark-gray, slightly sandy near top, calcareous, soft.....	42	0
T17	Limestone, pale yellowish-gray, sandy, medium-bedded; packed with bivalve shells.....	0	10
	Shale, medium greenish-gray, calcareous, soft...	17	0
T15	Shale, light olive-gray, calcareous, soft; ledge-forming; oyster-shells cover slope.....	11	0
	Shale, same as above but no oyster shells.....	9	0
T13	Siltstone, yellowish-gray, glauconitic, calcareous, medium-bedded; concentration of internal molds of ammonites; bivalves.....	1	0
T12	Siltstone, light-olive-green, calcareous, very shaly, soft; belemnites on slope.....	17	0
	Shale, dark-gray, calcareous, soft; belemnites on slope.....	7	0
	Claystone, medium olive-gray, calcareous, silty, soft.....	10	0

		Ft.	In.
	Shale, dark greenish-gray, calcareous, soft; belemnites on slope	9	0
	Thickness of Lower Shale Member	123	10
	Thickness of "Upper Sundance"	151	10
"Lower Sundance"			
Upper sandstone member			
	Sandstone, yellowish-tan, very fine-grained, calcareous, thick-bedded; finely cross-bedded throughout	17	0
	Sandstone, yellowish-tan, fine-grained, calcareous, thin-bedded and interference ripple-marked	3	0
TS7	Limestone, pale yellowish-brown, oolitic, ripple-marked, thin-bedded; bivalves	0	10
	Sandstone, light-tan, fine-grained, calcareous, thin-bedded; interference ripple-marked	3	0
	Siltstone, light-gray, calcareous, sandy	5	0
	Shale, dark-gray, calcareous, sandy, soft; interbedded with thin beds of yellowish-tan fine-grained sandstone	21	0
	Sandstone, yellowish-tan, fine-grained, calcareous, thick-bedded, soft	12	0
	Thickness of upper sandstone member	61	10
Middle shale member			
	Shale, medium-gray, calcareous, soft; underlain by gray limestone of Gypsum Spring Formation	14	0
	Thickness of "Lower Sundance"	75	0
	Total thickness of Sundance Formation	226	10

Cabin Creek

		Ft.	In.
Twin Creek Limestone			
Giraffe Creek Member			
	Limestone, medium-gray, very silty, bedding platy; overlain by greenish-gray and salmon-red siltstone of the Preuss	33	0
	Sandstone, light-tan, very fine-grained, very calcareous	4	0
	Thickness of Giraffe Creek Member.	37	0
Leeds Creek Member			
	Limestone, medium-gray, splintery, shaly	12	0
	Limestone, medium-gray, encrinal	0	10
	Limestone, medium-gray, splintery, shaly	15	0

		Ft.	In.
	Limestone, dark-gray, crystalline, medium-bedded; ledge forming	7	0
	Limestone, medium-gray, splintery, shaly	42	0
	Limestone, dark-gray, micrite	0	10
	Limestone, medium-gray, splintery, shaly	8	0
	Limestone, dark-gray, micrite	1	0
	Limestone, medium-gray, splintery, shaly	20	0
	Limestone, dark-gray, biosparite	0	4
	Limestone, medium-gray, splintery, shaly	2	0
	Limestone, dark-gray, micrite	1	0
	Limestone, medium-gray, splintery, shaly	5	0
	Limestone, dark-gray, micrite	1	0
	Limestone, medium-gray, splintery, shaly	12	0
CC22	Limestone, medium-gray, biosparite, shaly, platy; forms resistant ledge, bivalves	2	0
	Limestone, medium-gray, splintery, shaly	78	0
CC19-21	Limestone, medium-gray, splintery, very shaly; Gryphaea nebrascensis does not occur above this unit	56	0
	Siltstone, light maroonish-gray, very calcareous (slope mostly covered)	34	0
CC18	Limestone, medium light-gray, shaly, splintery, platy and burrowed; forms resistant ledge; bivalves	6	0
	Limestone, medium-gray, splintery, shaly	22	0
CC17[1], 16[2], 17[2]	Limestone, medium-gray, bedding platy, shaly; three ledge-forming limestones packed with bivalves separated by splintery shaly limestone	40	0
	Thickness of Leeds Creek Member	366	0
Walton Canyon Member			
	Siltstone, maroonish-tan, calcareous; blocky appearance	15	0
CC16	Limestone, biomicrite, medium light-gray, shaly, platy, burrowed, crinoid columnals, bivalves	6	0
CC15	Limestone, brownish-gray, crystalline, platy; non-resistant slope; bivalves 7 feet above base	22	0
	Limestone, medium-gray to maroonish-gray near the top; poorly washed oosparite, crinoid fragments, bedding platy; forms a resistant ledge	25	0

		Ft.	In.
	Shale, medium-gray, silty, calcareous, forms non-resistant slope	36	0
	Limestone, medium-gray, sparite, platy	7	0
	Limestone, dark-gray, micrite, bedding platy and symmetrically ripple-marked	6	0
	Limestone, very light-tan, oolitic, silty	4	0
	Thickness of Walton Canyon Member	121	0
Boundary Ridge Member			
	Shale, reddish-maroon, silty, calcareous, soft	32	0
CC8	Limestone, medium-gray, poorly washed, sandy, packed, oobiosparite; fragments of bivalves, crinoids, foraminifera, pellets, composite grains, sand filled burrows; medium-bedded, hard; bivalve fragments at base	10	0
	Siltstone, grayish-green, calcareous, soft	3	0
	Thickness of Boundary Ridge Member.	45	0
Rich Member			
	Limestone, medium-gray, oosparite	1	0
	Limestone, medium-gray, splintery, shaly	11	0
CC7	Limestone, light-gray, shaly, thin-bedded; relatively resistant bed; bivalves	2	0
	Limestone, medium-gray, splintery, shaly	10	0
	Limestone, medium-gray, hard, thin-bedded	10	0
	Limestone, medium-gray, splintery, shaly	49	0
CC6	Limestone, medium-gray, fossiliferous micrite, thin-bedded, symmetrically ripple-marked; bivalves gastropod and crinoid fragments	2	0
	Limestone, medium-gray, splintery, shaly	6	0
CC5	Limestone, medium-gray, fossiliferous micrite, thin-bedded; crinoid columnals scattered on bedding planes; interbedded with shaly splintery limestone; bivalves	4	0
	Limestone, medium-gray, splintery, shaly	12	0
CC3	Limestone, medium to dark-gray, micrite, medium-bedded, bivalves	2	0
	Thickness of Rich Member	109	0
Sliderock Member			
CC2	Limestone, dark-gray, splintery, medium to thin-bedded, shaly; bivalves 6 feet below top; occasional crinoid plates	40	0
	Thickness of Sliderock Member	40	0

Gypsum Spring Member	Ft.	In.
Limestone, light-gray to light-pink at base, fractured throughout (brecciated); underlain by white sandstone of Nugget Sandstone..	40	0
Total thickness of Twin Creek Limestone.....	758	0

APPENDIX C

Name and Location of Stratigraphic Sections (Localities shown in text-figure 1)

1. Buffalo Gap. Exposures on Beaver Creek, adjacent to Trout Haven Ranch, 2.9 miles west of State Highway 79. Improved light-duty road to Beaver Creek exists from highway 1.3 miles north of exit to the town of Buffalo Gap. Sec. 13, T6S, R6E, Custer County, South Dakota.

2. Minnekahta. Exposure on the south side of an improved light-duty road 3.2 miles west from its intersection with State Highway 89. Sec. 11, T7S, R3E, Fall River County, South Dakota.

3. Minnekahta. Outcrop on the north side of an improved light-duty road 7.3 miles west from its intersection with State Highway 89. Sec. 13, T7S, R3E, Fall River County, South Dakota.

4. Rapid City. Road cut on Federal Highway 16, 5 miles south of the southern limit of Rapid City. Sec. 34, T1N, R7E, Pennington County, South Dakota.

5. Spearfish. Cliff face at the eastern end of an improved light-duty road 2.0 miles east of its cutoff from Federal Highway 85. This cutoff is 1.9 miles north of Lookout Memorial Hospital on Highway 85 on the northern outskirts of Spearfish. Sec. 36, T7N, R2E, Lawrence County, South Dakota.

6. Newcastle. Exposure side of unimproved light-duty road #124 on east side of Elk Mountain. Road #124 exists west from improved light-duty road #769 (which connects with Federal Highway 16) 18 miles east of Newcastle. Secs. 18 & 19, T4S, R1E, Custer County, South Dakota.

7. Farthing. Exposure on side of Middle Chugwater Creek, 1.9 miles west of railroad crossing at Farthing. Sec. 4, T18N, R70W, Laramie County, Wyoming.

8. Freezeout Mountains. Outcrop on east side of unimproved light-duty road 2 miles west of its intersection with State Highway 487. Dirt road exit is 14 miles north of Medicine Bow. Sec. 29, T25N, R78W, Carbon County, Wyoming.

9. Douglas. Section on the property of Robert Haefeler, whose ranch is 5.6 miles south of Center St. in Douglas. Sec. 8, T31N, R71W, Commerce County, Laramie.

10. Lander. Exposures 3 miles east of Lander, just north of State Highway 789. Sec. 19, T2S, R2E, Freemont County, Wyoming.

11. Maverick Spring. Outcrops in Maverick Spring Dome Oil Field, 19 miles north of Pilot Butte Oil Field, just off of Federal Highway 26. Secs. 23 & 26, T6N, R2W, Freemont County, Wyoming.

12. Vinceant Ranch. Exposures on the east side of Twin Creek, 3 miles south of Federal Highway 287. Sec. 13, T31N, R97W, Freemont County, Wyoming.

13. Alcova. Cut on the north side of an oiled road 1 mile east of Alcova Reservoir Dam or 2 miles east of Alcova on State Highway 220. Sec. 30, T30N, R82W, Natrona County, Wyoming.

14. Seminoe Dam. Outcrops on south side of improved light-duty road, 4.5 miles south of Seminoe Dam. Sec. 20, T25N, R85W, Carbon County, Wyoming.

15. Bull Lake. Exposure on the north shore of Bull Lake Reservoir at the south end of the reservoir. Sec. 31, T3N, R3W, Fremont County, Wyoming.

16. Cody. Exposure on the north side of Trail Creek 1 mile northwest of Newton Lakes on the northwestern outskirts of Cody. Sec. 22, T53N, R102W, Park County, Wyoming.

17. Lovell. Roadside exposures along an improved light-duty road leading to Georgia Pacific Bestwall Gypsum Plant. Road joins State Highway 789 7.1 miles south of Lovell. Section 2.4 miles west of Highway 789. Sec. 28, T56N, R95W, Bighorn County, Wyoming.

18. Thermopolis. Outcrop on west side of State Highway 789, 2.0 miles north of Thermopolis. Sec. 25, T43N, R95W, Hot Springs County, Wyoming.

19. Hyattville. Exposure 3.5 miles southeast of Hyattville. Sec. 16, T49N, R89W, Bighorn County, Wyoming.

20. Tensleep. Exposure on east side of Upper Nowood Road, 18 miles south of Tensleep. Sec. 6, T44N, R87W, Washakie County, Wyoming.

21. Cabin Creek. Outcrop 7.5 miles south of junction of Federal Highways 89 & 26 with 189 & 187. Sec. 17, T38N, R116W, Teton County, Wyoming.

22. Ditch Creek. Exposure on north side of unimproved light-duty road, 7.3 miles east of Elbow Ranch. Sec. 11, T43N, R114W, Teton County, Wyoming.

23. Lower Slide Lake. Exposure at west end of Lower Slide Lake. Sec. 4 & 5, T42N, R114W, Teton County, Wyoming.

APPENDIX D

Stratigraphic Positions of Macrofossil Collections

Buffalo Gap

BG6: Internal molds of Tancredia sp. cf. T. warrenana (Meek & Hayden), Meleagrinella curta (Hall), and Vaugonia conradi (Meek & Hayden).

BG12: Internal molds of Meleagrinella curta (Hall).

BG14: Internal molds of Quenstedtia sp.

Minnekahta

M4: Fragments of Ostrea strigilecula (White) occur in stringers.

M6: Internal molds of Vaugonia conradi (Meek & Hayden).

M9-M12, M15: Shale and occasional sand stringers, containing an abundance of Meleagrinella curta (Hall).

M14: Surface covered with Meleagrinella curta (Hall).

Minnekahta

M3: Meleagrinella curta (Hall).

M4: Surface covered with Meleagrinella curta (Hall).

M5-M8: An abundance of Meleagrinella curta (Hall).

Rapid City

RC3: Surface covered with very small molds of Tancredia sp.

RC5: Surface covered mostly with Meleagrinella curta (Hall), and a few Tancredia sp. and Quenstedtia sp.

RC20: Surface covered with Meleagrinella curta (Hall), and Tancredia sp.

RC22, RC23: Occasional Lingula brevirostris (Meek & Hayden).

RC26: Tancredia sp.

Newcastle

N2: Fragments of Ostrea strigilecula (White).

N3: Fossiliferous shale nodules contain Meleagrinella curta (Hall), Nucula sp., Gryphaea nebrascensis (Meek & Hayden), Camptonectes platessiformis (White), Myophorella montanaensis (Meek), Tancredia sp., Lima sp.

N4: Ostrea strigilecula (White), Camptonectes platessiformis (White), Gryphaea nebrascensis (Meek & Hayden), Quenstedtia sublevis (Meek & Hayden), Meleagrinella curta (Hall), Myophorella sp., Nucula sp.

N5: Myophorella montanaensis (Meek), Camptonectes platessiformis (White), Gryphaea nebrascensis (Meek & Hayden), Trigonia americana (Meek).

N6-N11: Meleagrinella curta (Hall).

N12: Meleagrinella curta (Hall) on surface.

N42: Abundance of Ostrea strigilecula (White) and Camptonectes bellistriatus (Meek).

N45: Fragments of Ostrea strigilecula (White).

Freezeout Mountains

FM21: Fragments of Ostrea strigilecula (White) and internal molds of Tancredia sp. cf. T. transversa (Whitfield & Hovey), Meleagrinella curta (Hall), Tancredia sp.

FM22: Surface cover of Meleagrinella curta (Hall), Ostrea strigilecula (White), and Tancredia sp.

FM24: Fragments of Ostrea strigilecula (White), and Camptonectes sp. Lime nodules bearing Tancredia sp. cf. T. transversa (Whitfield & Hovey), and Nucula sp.

FM25, 26: Meleagrinella curta (Hall), Astarte sp.

FM30: Top sand contains Meleagrinella curta (Hall), Tancredia sp. Coquina below contains Ostrea strigilecula (White), and Camptonectes bellistriatus (Meek).

FM34: This sample was not found in place but on slope. Its stratigraphic horizon is assumed on the basis of a similar

lithologic and fossiliferous unit at the top of the Redwater Shale Member of the Sundance Formation at Douglas, Wyoming. Sandstone, very fine grained to fine-grained, light olive-gray, very calcareous and glauconitic, thin-bedded, and symmetrically rippled. Surface bears mostly Tancredia transversa (Whitfield & Hovey), with a few fragments of Camptonectes sp., Ostrea strigilecula (White), and Meleagrinella curta (Hall).

Douglas

D2: Grammatodon haguei (Meek).

D4: Meleagrinella curta (Hall).

D10: Surface covered with very small internal molds of Tancredia sp., cf. T. warrenana (Meek & Hayden).

D11, 12: Occasional Tancredia sp. cf. T. warrenana (Meek & Hayden), and Meleagrinella curta (Hall).

D26: Valves of Camptonectes bellistriatus (Meek) occur throughout.

D38: Tancredia transversa (Whitfield & Hovey), Meleagrinella curta (Hall).

Lander

L1: Astarte packardi (White).

L3: Astarte packardi (White), Mytilus sp., Pronoella sp.

L15: Valves of Ostrea strigilecula (White) and Camptonectes bellistriatus (Meek).

L16: Camptonectes bellistriatus (Meek), Astarte packardi (White).

L21: Camptonectes bellistriatus (Meek), Pleuromya sp. ?

L23, 24: Ostrea strigilecula (White).

L25: Modiolus formosus (Meek & Hayden), Ostrea strigilecula (White), Camptonectes bellistriatus (Meek), Pleuromya newtoni (Whitfield), Astarte sp.

L29: Camptonectes bellistriatus (Meek), Ostrea strigilecula (White).

Maverick Spring

MS1: Bryozoa and gastropod (Lyosoma sp. ?) fragments.

MS2: Camptonectes platessiformis (White).

MS3: Ostrea strigilecula (White).

MS4: Trigonia sp., Pleuromya sp., Camptonectes sp. ? and Gryphaea sp. ?

MS6: Pronoella cinnabarensis (Stanton), Vaugonia conradi (Meek & Hayden), Astarte packardi (White), Pleuromya subcompressa (Meek), Mactromya ? sp., Neritoma ? occidentalis (Whitfield & Hovey), Trigonia sp., Tancredia sp.

MS7: Modiolus subimbricatus (Meek), Neritoma ? occidentalis (Whitfield & Hovey).

MS8: Gryphaea nebrascensis (Meek & Hayden) shell fragments.

MS9: Pronoella cinnabarensis (Stanton), Tancredia sp.

MS10: Pronoella cinnabarensis (Stanton), Ostrea strigilecula (White), Lyosoma ? sp.

MS12: Vaugonia conradi (Meek & Hayden), Pronoella sp.

MS14: Pronoella cinnabarensis (Stanton), Pleuromya subcompressa (Meek), Thracia sp. ?

MS17: Camptonectes platessiformis (White), Meleagrinella curta (Hall), Ostrea strigilecula (White).

MS18: Gryphaea nebrascensis (Meek & Hayden), Ostrea strigilecula (White).

MS19-23: Gryphaea nebrascensis (Meek & Hayden).

MS24: Gryphaea nebrascensis (Meek & Hayden), Grammatodon haguei (Meek), Ostrea strigilecula (White), Astarte packardi (White).

MS25: Gryphaea nebrascensis (Meek & Hayden).

MS29: Gryphaea nebrascensis (Meek & Hayden), Camptonectes platessiformis (White).

MS36: Abundant Alectryonia procumbens (White).

MS38: Ostrea strigilecula (White).

MS45: Camptonectes bellistriatus (Meek), Modiolus sp.

MS46: Kallirhynchia myrina (Hall & Whitfield), Ostrea strigilecula (White).

MS50, 51,54: Kallirhynchia myrina (Hall & Whitfield), Camptonectes bellistriatus (Meek), Ostrea strigilecula (White), Gryphaea sp.

MS58: Camptonectes bellistriatus (Meek), Ostrea strigilecula (White).

Vinceants Ranch

V19: Pholadomya sp.

V20: Camptonectes bellistriatus (Meek), Ostrea strigilecula (White), belemnite fragments.

V22,26, 27: Camptonectes bellistriatus (Meek), Pleuromya newtoni (Whitfield), Tancredia sp., Idonearca? sp.

V30: Vaugonia sturgisensis (Whitfield & Hovey), Pronoella sp., Camptonectes bellistriatus (Meek).

V32: Ostrea strigilecula (White), Camptonectes bellistriatus (Meek).

V33: Camptonectes bellistriatus (Meek).

V34: Ostrea strigilecula (White).

V35: Camptonectes bellistriatus (Meek).

V36: Ostrea strigilecula (White), Camptonectes bellistriatus (Meek).

V38: Camptonectes bellistriatus (Meek).

Alcova

A7: Meleagrinella curta (Hall).

A11: Quenstedtia sp., Tancredia sp.

A21: Meleagrinella curta (Hall), Ostrea strigilecula (White), Tancredia sp.

A32,33: Camptonectes bellistriatus (Meek), Ostrea strigilecula (White), Modiolus sp., Pleuromya newtoni (Whitfield), Tancredia transversa (Whitfield and Hovey), Astarte sp., Pleuromya sp., Pronoella ? sp.

A35: Camptonectes bellistriatus (Meek).

Seminoe Dam

SD22,23: Camptonectes bellistriatus (Meek), Ostrea strigilecula (White), Tancredia transversa (Whitfield and Hovey).

SD24: Camptonectes bellistriatus (Meek).

Bull Lake

BL5: Vaugonia conradi (Meek & Hayden).

BL8,9: Gryphaea nebrascensis (Meek & Hayden).

BL10: Gryphaea nebrascensis (Meek & Hayden), Meleagrinella curta (Hall), Astarte sp. ?

BL12: Gryphaea nebrascensis (Meek & Hayden).

BL18: Camptonectes bellistriatus (Meek).

BL23: Camptonectes bellistriatus (Meek).

BL24: Contains belemnite shells. Camptonectes bellistriatus (Meek).

BL25: Ostrea strigilecula (White), Tancredia sp.

BL26: Camptonectes bellistriatus (Meek).

BL28: Ostrea strigilecula (White), Meleagrinella curta (Hall), Kallirhynchia myrina (Hall & Whitfield), Tancredia transversa (Whitfield & Hovey).

Cody

C1: Trigonia americana (Meek), Pronoella cinnabarensis (Stanton), Modiolus subimbricatus (Meek), Corbula? sp., Astarte meeki (Stanton), Prorokia fontenellensis (Imlay).

C2: Trigonia americana (Meek), Modiolus subimbricatus (Meek).

C4: Ostrea strigilecula (White), Pronoella cinnabarensis (Stanton), Camptonectes platessiformis (White), Modiolus subimbricatus (Meek), Mytilus whitei (Whitfield).

C5: Camptonectes platessiformis (White), Ostrea strigilecula (White).

C6: Actinastrea hyatti (Wells).

C8, 13: Gryphaea nebrascensis (Meek & Hayden).

C14: Gryphaea nebrascensis (Meek & Hayden).

C18: Meleagrinella curta (Hall).

C21: Tancredia transversa (Whitfield & Hovey).

C25: Tancredia sp., Ostrea strigilecula (White).

Lovell

LV1: Modiolus subimbricatus (Meek), Ostrea strigilecula (White), Astarte packardi (White), Camptonectes platessiformis (White), Vaugonia conradi (Meek & Hayden), Pleuromya sp.

LV2: Pleuromya subcompressa (Meek), Ostrea strigilecula (White), Modiolus subimbricatus (Meek), Vaugonia conradi (Meek & Hayden).

LV4-6, 8: Gryphaea nebrascensis (Meek & Hayden).

LV15: Ostrea engelmanni (Meek), Gryphaea nebrascensis (Meek & Hayden).

LV17: Camptonectes bellistriatus (Meek).

LV23: Ostrea strigilecula (White), Vaugonia sturgisensis (Whitfield & Hovey), Tancredia sp., Modiolus sp., Idonarca sp.

Thermopolis

T8: Mytilus whitei (Whitfield), Camptonectes platessiformis (White).

T14: Pleuromya newtoni (Whitfield), Camptonectes bellistriatus (Meek), Ostrea strigilecula (White).

T16: Camptonectes bellistriatus (Meek), Ostrea strigilecula (White).

T19: Ostrea englemanni (Meek), Camptonectes bellistriatus (Meek).

T21: Camptonectes bellistriatus (Meek).

Hyattville

HV10: Camptonectes bellistriatus (Meek), Ostrea sp.

HV17: Ostrea strigilecula (White), Meleagrinella curta (Hall), Tancredia sp.

HV19: Meleagrinella curta (Hall), Ostrea sp., Platymyoidea sp., Tancredia sp., Vaugonia sturgisensis (Whitfield & Hovey), Pleuromya sp.

HV21: Meleagrinella curta (Hall), Tancredia sp. cf. T. warrenana (Meek & Hayden), Ostrea sp.

Tensleep

TS7: Meleagrinella curta (Hall).

TS12: Pleuromya sp.

TS13: Ostrea strigilecula (White), Grammatodon haguei (Meek), Pleuromya sp.

TS15: Ostrea engelmanni (Meek), Pleuromya sp.

TS17: Camptonectes bellistriatus (Meek), Ostrea engelmanni (Meek).

TS22: Ostrea strigilecula (White), Meleagrinella curta (Hall), Tancredia sp.

TS23: Meleagrinella curta (Hall), Tancredia sp.

Cabin Creek

CC2: Astarte meeki (Stanton), Thracia weedi (Stanton), Camptonectes stygius (White).

CC3: Camptonectes stygius (White), Gryphaea planoconvexa (Imlay).

CC5: Gryphaea planoconvexa (Imlay), Ostrea strigilecula (White), Astarte meeki (Stanton), Camptonectes platessiformis (White).

CC6: Ostrea strigilecula (White), Astarte meeki (Stanton), Prorokia fontenellensis (Imlay), Camptonectes sp., Pleuromya subcompressa (Meek), Thracia weedi (Stanton).

CC7: Plicatula sp., Astarte meeki (Stanton), Camptonectes stygius (White), Corbula sp. cf. C. munda (McLearn).

CC8: Camptonectes stygius (White).

CC15: Camptonectes stygius (White), Ostrea strigilecula (White), Myophorella montanaensis (Meek).

CC16[1]: Camptonectes stygius (White), Lima sp.

CC17[1], 16[2], 17[2]: Camptonectes stygius (White).

CC18: Myopholas hardyi (Imlay), Astarte meeki (Stanton), Pronoella? sp.

CC19-21: Gryphaea nebrascensis (Meek & Hayden).

CC22: Camptonectes stygius (White), Ostrea strigilecula (White).

Ditch Creek

DC6: Pleuromya subcompressa (Meek), Gryphaea planoconvexa (Whitfield), Pholadomya kingi (Meek), Vaugonia conradi (Meek & Hayden), Corbula munda (McLearn), Platymyoidea rockymontana (Imlay), Ostrea strigilecula (White), Gervillia montanaensis (Meek), Lima occidentalis (Hall & Whitfield), Idonearca haguei (Stanton), Newtonia occidentale (Hall & Whitfield), Pleuromya sp., Camptonectes platessiformis (White), Pinna kingi (Meek), Astarte meeki (Stanton), Pronoella sp., Myophorella montanaensis (Meek), Thracia weedi (Stanton), Modiolus subimbricatus (Meek), Isognomon perplana (Whitfield).

DC7: Astarte meeki (Stanton), Corbula munda (McLearn), Pleuromya subcompressa (Meek).

DC9[1]: Pholadomya kingi (Meek), Platymyoidea rockymontana (Imlay), Pleuromya subcompressa (Meek).

DC9[2]: Grammatodon haguei (Meek), Astarte meeki (Stanton), Corbula? sp., Thracia weedi (Stanton), Pronoella cinnabarensis (Stanton).

DC11: Gryphaea nebrascensis (Meek & Hayden), Myopholas hardyi (Imlay).

DC13: Gryphaea nebrascensis (Meek & Hayden), Astarte meeki (Stanton), Modiolus subimbricatus (Meek), Pronoella cinnabarensis (Stanton).

DC15: Gryphaea nebrascensis (Meek & Hayden), Ostrea strigilecula (White).

Lower Slide Lake

Rich Member: Gryphaea planoconvexa (Whitfield), Astarte meeki (Stanton), Gervillia montanaensis (Meek), Vaugonia conradi (Meek & Hayden), Myophorella sp., Pleuromya subcompressa (Meek), Homomya gallatinensis (Stanton), Cercomya punctata (Stanton), Pholadomya kingi (Meek), Pinna kingi (Meek), Camptonectes platessiformis (White), Trigonia americana (Meek), Lima occidentalis (Hall & Whitfield), Ostrea strigilecula (White), Pronoella sp., Mactromya? sp., Modiolus subimbricatus (Meek), Corbula sp., Pleuromya sp.

Stump Fm.: Kallirhynchia myrina (Hall & Whitfield).

APPENDIX E

Stratigraphic Positions of Microfossil Collections
Figure at left of each species represents number of specimens

From each selected channel sample 300 grams of sediment was washed and wet-sieved in the laboratory for foraminifera and ostracods. Foraminifera were counted directly. Direct counts of ostracods cannot be made because during growth they molt their shells. Potentially, valves from eight instar stages plus the adult may be from a single individual. The method used to count the number of ostracods was to total the number of whole shells with the greatest number of either right or left valves of the juveniles, males and females.

Quaternary-O was used to deflocculate the dry samples. It does an excellent job on calcareous shales or claystones. The following procedure was used: (1) Cover 300 gms of sample with diluted (directions with stock solution) Q-O solution and let stand overnight, (2) simmer on a hot plate for approximately one hour, (3) wet-sieve the entire sample through a 100-mesh screen, first with cold water, then with warm water in order to clean the surface of the shells, and (4) dry residue and dry-sieve to pick desired size fraction.

Section 6. Newcastle, Wyoming.

Samples N4, 9-11, 22, 24, 25, 36, 39, 43, 47, and 48 yielded no microfossils.

Sample N44.

Ostracoda

5 Aparchitocythere typica Swain & Peterson
4 Leptocythere imlayi Swain & Peterson

Foraminifera

5 Lenticulina audax Loeblich & Tappan
2 Astacolus agalmatus Loeblich & Tappan

Sample N41.

Ostracoda

1 Aparchitocythere typica Swain & Peterson
1 Leptocythere imlayi Swain & Peterson

Foraminifera

9 Lenticulina audax Loeblich & Tappan

Sample N40.

Ostracoda

5 Cytherella paramuensteri Swain & Peterson
1 Aparchitocythere loeblichorum Swain & Peterson
4 A. typica Swain & Peterson
1 Monoceratina sundancensis Swain & Peterson
2 Macrocypris minutus Swain & Peterson
2 Leptocythere imlayi Swain & Peterson

Foraminifera

3 Lenticulina audax Loeblich & Tappan

Sample N38.

Ostracoda

1 Cytherella paramuensteri Swain & Peterson

Foraminifera

13 Lenticulina audax Loeblich & Tappan

Sample N20.

Ostracoda

11 Aparchitocythere compressa Peterson
2 Paracypris projecta Peterson

Sample N8.

Ostracoda

31 Aparchitocythere compressa Peterson
134 Cytherella paramuensteri Swain & Peterson

Sample N7.

Ostracoda

65 Aparchitocythere compressa Peterson
87 Cytherella paramuensteri Swain & Peterson

Sample N6.

Ostracoda

23 Aparchitocythere compressa Peterson
111 Cytherella paramuensteri Swain & Peterson

Section 9. Douglas, Wyoming.

Samples D8, 9, 15, 19, 20, 22, 23, 25 33, 35, and 36 yielded no microfossils.

Sample D34.

Foraminifera

1 Lenticulina audax Loeblich & Tappan
1 Ammobaculites cobbani Loeblich & Tappan

Sample D32.

Foraminifera

17 Lenticulina audax Loeblich & Tappan
5 Astacolus agalmatus Loeblich & Tappan
2 Dentalina ectadia Loeblich & Tappan
1 Ammobaculites sp.
1 A. cobbani Loeblich & Tappan

Sample D30.

Foraminifera

3 Lenticulina audax Loeblich & Tappan
10 Ammomarginulina baryntica Loeblich & Tappan
5 Ammobaculites imlayi Loeblich & Tappan
9 A. cobbani Loeblich & Tappan
20 Reophax sundancensis Loeblich & Tappan

Sample D18.

Foraminifera

1 Lenticulina cf. L. audax Loeblich & Tappan

Sample D7.

Ostracoda

11 Aparchitocythere compressa Peterson

Sample D6.

Foraminifera

2 Lenticulina cf. L. audax Loeblich & Tappan

Sample D4.

Ostracoda

18 Cytherella paramuensteri Swain & Peterson
1 Bythocypris jurassica Peterson

Foraminifera

1 Lenticulina cf. L. audax Loeblich & Tappan

Section 20. Tensleep, Wyoming.

Samples TS 3-6, 11, and 12 yielded no microfossils.

Sample TS21.

Ostracoda

3 Aparchitocythere typica Swain & Peterson

Sample TS20.

Ostracoda

1 Aparchitocythere typica Swain & Peterson

Foraminifera

1 Dentalina ectadia Loeblich & Tappan

Sample TS19.

Ostracoda

13 Aparchitocythere typica Swain & Peterson

Foraminifera

1 Ammomarginulina baryntica Loeblich & Tappan

Sample TS18.

Ostracoda

1 Leptocythere imlayi Swain & Peterson

Sample TS16.

Ostracoda

52 Cytherella paramuensteri Swain & Peterson
23 Cythereis zygoventralis Swain & Peterson
64 Aparchitocythere typica Swain & Peterson

Foraminifera

7 Lenticulina audax Loeblich & Tappan
1 Astacolus agalmatus Loeblich & Tappan
1 Citharina sp.
2 C. entypomatus Loeblich & Tappan
2 Citharinella sp.

Sample TS15.

Ostracoda

6 Cytherella paramuensteri Swain & Peterson

5 Aparchitocythere typica Swain & Peterson
4 Camptocythere elliptica Swain & Peterson
1 Macrocypris minutus Swain & Peterson

Foraminifera
79 Lenticulina audax Loeblich & Tappan
15 Astacolus agalmatus Loeblich & Tappan
5 Citharina entypomatus Loeblich & Tappan
1 Reophax sundancensis Loeblich & Tappan

Sample TS14.

Ostracoda
4 Aparchitocythere typica Swain & Peterson
1 Leptocythere imlayi Swain & Peterson
2 Progonocythere crowcreekensis Swain & Peterson

Foraminifera
6 Lenticulina audas Loeblich & Tappan
17 Astacolus agalmatus Loeblich & Tappan
1 Citharina entypomatus Loeblich & Tappan
1 Citharinella sp.

Sample TS10.

Foraminifera
5 Ammobaculites venustus Loeblich & Tappan
4 Ammomarginulina baryntica Loeblich & Tappan

Sample TS9.

Foraminifera
1 Citharina entypomatus Loeblich & Tappan
1 Astacolus agalmatus Loeblich & Tappan
1 Lenticulina audax Loeblich & Tappan
12 Ammomarginulina baryntica Loeblich & Tappan
4 Ammobaculites cobbani Loeblich & Tappan

Sample TS1.

Ostracoda
11 Cytherella paramuensteri Swain & Peterson
21 Aparchitocythere compressa Peterson
4 A. elongata Peterson

Foraminifera
1 Lenticulina cf. L. audax Loeblich & Tappan

Section 11. Maverick Spring Anticline, Wyoming.

Samples MS 7, 19, 20, 52, and 57 yielded no microfossils.

Sample MS45.

Ostracoda

10 Aparchitocythere typica Swain & Peterson
1 A. loeblichorum Swain & Peterson
1 Cytherella paramuensteri Swain & Peterson
1 Camptocythere elliptica Swain & Peterson

Foraminifera

3 Ammobaculites imlayi Loeblich & Tappan

Sample MS41.

Ostracoda

1 Cythereis zygoventralis Swain & Peterson
1 Aparchitocythere typica Swain & Peterson

Foraminifera

1 Lenticulina audax Loeblich & Tappan

Sample MS40.

Ostracoda

1 Aparchitocythere typica Swain & Peterson
2 Monoceratina sundancensis Swain & Peterson

Foraminifera

4 Astacolus agalmatus Loeblich & Tappan
4 Lenticulina audax Loeblich & Tappan
4 Citharina entypomatus Loeblich & Tappan
2 Reophax sundancensis Loeblich & Tappan

Sample MS39.

Ostracoda

2 Aparchitocythere typica Swain & Peterson
2 Camptocythere elliptica Swain & Peterson

Foraminifera

2 Citharina entypomatus Loeblich & Tappan
1 Citharinella sp.

Sample MS38.

Ostracoda

1 Monoceratina sundancensis Swain & Peterson
21 Aparchitocythere typica Swain & Peterson
2 A. loeblichorum

Foraminifera

17 Lenticulina audax Loeblich & Tappan
3 Astacolus agalmatus Loeblich & Tappan
2 A. ophrastus Loeblich & Tappan
5 Citharina entypomatus Loeblich & Tappan

Sample MS37.

Ostracoda

1 Aparchitocythere typica Swain & Peterson

Sample MS29.

Ostracoda

1 Cytherella paramuensteri Swain & Peterson
2 Cytheropteron scalpella Peterson
8 Procytheridea exempla Peterson

Foraminifera

19 Lenticulina dilecta Loeblich & Tappan
112 L. cf. L. audax Loeblich & Tappan
8 Marginulinopsis phragmites Loeblich & Tappan
6 Astacolus ectypus Loeblich & Tappan
1 A. petalus Loeblich & Tappan
1 Nodosaria sphingothalama Loeblich & Tappan
5 Citharina entypomatus Loeblich & Tappan
3 Vaginulina compsa Loeblich & Tappan

Sample MS28.

Ostracoda

6 Paracypris projecta Peterson
27 Procytheridea exempla Peterson

Foraminifera

7 Lenticulina cf. L. audax Loeblich & Tappan
5 Astacolus ectypus Loeblich & Tappan
5 Vaginulina compsa Loeblich & Tappan
6 Citharina entypomatus Loeblich & Tappan
2 C. latissima Loeblich & Tappan

Sample MS27.

Ostracoda

10 Procytheridea exempla Peterson
1 P. crassa Peterson
2 Paracypris projecta Peterson

Foraminifera

3 Astacolus ectypus Loeblich & Tappan
2 Vaginulinopsis eritheles Loeblich & Tappan
6 Lenticulina dilecta Loeblich & Tappan
45 L. cf. L. audax Loeblich & Tappan
1 Vaginulina compsa Loeblich & Tappan
1 Nodosaria sphingothalama Loeblich & Tappan

Sample MS26.

Ostracoda

4 Procytheridea exempla Peterson

5	Paracypris projecta Peterson
	Foraminifera
55	Lenticulina cf. L. audax Loeblich & Tappan
1	L. dilecta Loeblich & Tappan
1	Astacolus ectypus Loeblich & Tappan
1	Citherina entypomatus Loeblich & Tappan
2	Dentalina ejuncida Loeblich & Tappan

Sample MS25.

	Ostracoda
7	Procytheridea exempla Peterson
1	Cytherella paramuensteri Swain & Peterson
1	Monoceratina pararossae Peterson
4	Paracypris projecta Peterson
	Foraminifera
3	Citharina latissima Loeblich & Tappan
4	Marginulinopsis phragmites Loeblich & Tappan
9	Citharina entypomatus Loeblich & Tappan
2	Dentalina polyholca Loeblich & Tappan
2	Nodosaria sphingothalama Loeblich & Tappan
20	Astacolus ectypus Loeblich & Tappan
5	A. agalmatus Loeblich & Tappan
1	Vaginulinopsis eritheles Loeblich & Tappan
65	Lenticulina cf. L. audax Loeblich & Tappan
1	Frankeina commutata Loeblich & Tappan

Sample MS24.

	Ostracoda
13	Procytheridea exempla Peterson
9	Paracypris projecta Peterson
1	Cytherelloidea recurvata Peterson
	Foraminifera
1	Marginulinopsis phragmites Loeblich & Tappan
20	Lenticulina cf. L. audax Loeblich & Tappan
3	Lingulina hathra Loeblich & Tappan
5	Astacolus ectypus Loeblich & Tappan
2	Citharina latissima Loeblich & Tappan
1	Vaginulina compsa Loeblich & Tappan
1	Nodosaria sp.

Sample MS23.

	Ostracoda
9	Procytheridea exempla Peterson
1	P. minuta Peterson
1	Paracypris projecta Peterson

Foraminifera

1 Lingulina hathra Loeblich & Tappan
3 Citharina latissima Loeblich & Tappan
2 C. entypomatus Loeblich & Tappan
1 Citharinella compara Loeblich & Tappan
2 Lenticulina cf. L. audax Loeblich & Tappan

Sample MS22.

Ostracoda

32 Procytheridea exempla Peterson
8 P. minuta Peterson
3 Monoceratina pararossae Peterson
2 Cytherelloidea recurvata Peterson
6 Cythereis sp.
2 C. heteromorpha Peterson

Foraminifera

23 Marginulinopsis phragmites Loeblich & Tappan
6 Citharinella compara Loeblich & Tappan
2 Lingulina rursa Loeblich & Tappan
1 Citharina entypomatus Loeblich & Tappan
40 Astacolus ectypus Loeblich & Tappan
6 A. agalmatus Loeblich & Tappan
6 A. petalus Loeblich & Tappan
9 Lenticulina cf. L. audax Loeblich & Tappan
2 Vaginulina compsa Loeblich & Tappan
1 Nodosaria sphingothalama Loeblich & Tappan
1 Lingulina hathra Loeblich & Tappan
1 Dentalina ochyra Loeblich & Tappan
8 D. ectadia Loeblich & Tappan
1 D. gracilistriata Loeblich & Tappan

Sample MS21.

Ostracoda

37 Procytheridea exempla Peterson
1 P. minuta Peterson
3 P. crassa Peterson
2 Paracypris projecta Peterson
1 Cytherella paramuensteri Swain & Peterson
1 Monoceratina pararossae Peterson
1 Cytherelloidea recurvata Peterson

Foraminifera

3 Lingulina hathra Loeblich & Tappan
1 Marginulinopsis phragmites Loeblich & Tappan
2 Citharina entypomatus Loeblich & Tappan
11 Astacolus ectypus Loeblich & Tappan
1 Vaginulina compsa Loeblich & Tappan
1 Dentalina polyholca Loeblich & Tappan

Sample MS18.

Ostracoda

105 Procytheridea exempla Peterson
17 P. minuta Peterson
7 P. crassa Peterson
7 Paracypris projecta Peterson
2 Monoceratina pararossae Peterson
2 Cytherelloidea recurvata Peterson

Foraminifera

2 Citharinella compara Loeblich & Tappan
2 Nodosaria sphingothalama Loeblich & Tappan
1 Dentalina polyholca Loeblich & Tappan
5 Citharina entypomatus Loeblich & Tappan
16 Vaginulina mecyna Loeblich & Tappan
2 V. compsa Loeblich & Tappan

Sample MS16.

Ostracoda

6 Monoceratina sundancensis Swain & Peterson
38 Procytheridea exempla Peterson
6 P. minuta Peterson
1 Cytherelloidea recurvata Peterson
1 Cytherella paramuensteri Swain & Peterson
1 Paracypris projecta Peterson

Foraminifera

3 Astacolus ectypus Loeblich & Tappan
3 A. petalus Loeblich & Tappan
8 Citharinella compara Loeblich & Tappan
27 Vaginulina mecyna Loeblich & Tappan
4 Vaginulina sp.
13 Citharina latissima Loeblich & Tappan
10 C. entypomatus Loeblich & Tappan
30 Dentalina ectadia Loeblich & Tappan
1 D. gracilistriata Loeblich & Tappan
1 Lingulina hathra Loeblich & Tappan
1 Eoguttulina axilla Lalicker
2 Paleopolymorphina sp.
5 Vaginulinopsis sp.

Sample MS15.

Ostracoda

9 Procytherudea exempla Peterson
3 P. crassa Peterson
4 P. minuta Peterson
2 Monoceratina sundancensis Swain & Peterson
12 Cytherella paramuensteri Swain & Peterson

3	Paracypris projecta Peterson
1	Cytherelloidea recurvata Peterson
7	Bythocypris jurassica Peterson
2	Cythereis heteromorpha Peterson
	Foraminifera
1	Nodosaria orthostoecha Loeblich & Tappan
2	Dentalina polyholca Loeblich & Tappan
11	Vaginulina mecyna Loeblich & Tappan
1	Lingulina rursa Loeblich & Tappan
5	Dentalina ectadia Loeblich & Tappan
1	Eoguttulina axilla Lalicker
1	Citharina latissima Loeblich & Tappan
1	C. entypomatus Loeblich & Tappan

Sample MS13.

	Ostracods
9	Cytherella paramuensteri Swain & Peterson
1	Cytherelloidea recurvata Peterson
3	Procytheridea exempla Peterson
2	P. crassa Peterson
1	P. minuta Peterson
21	Paracypris projecta Peterson
109	Monoceratina sundancensis Swain & Peterson
	Foraminifera
3	Vaginulina mecyna Loeblich & Tappan
1	Eoguttulina axilla Lalicker

Sample MS11.

	Ostracoda
2	Paracypris projecta Peterson
4	Cytherella paramuensteri Swain & Peterson
1	Bythocypris jurassica Peterson
2	Cytherelloidea recurvata Peterson
24	Monoceratina sundancensis Swain & Peterson
2	Procytheridea minuta Peterson
	Foraminifera
8	Vaginulina mecyna Loeblich & Tappan
1	Dentalina gracilistriata Loeblich & Tappan
4	Marginulina sp.
3	Astacolus cf. A. ectypus Loeblich & Tappan

Sample MS5.

	Ostracoda
14	Paracypris projecta Peterson
2	Cytherella paramuensteri Swain & Peterson

54 Monoceratina sundancensis Swain & Peterson
5 Procytheridea exempla Peterson

Sample MS4.

Ostracoda
92 Monoceratina sundancensis Swain & Peterson
2 Cytherella paramuensteri Swain & Peterson
1 Procytheridea exempla Peterson
2 P. crassa Peterson

Foraminifera
1 Vaginulina mecyna Loeblich & Tappan

Sample MS2.

Ostracoda
65 Paracypris projecta Peterson
10 Monoceratina sundancensis Swain & Peterson
42 Procytheridea exempla Peterson
4 P. crassa Peterson
3 P. minuta Peterson
18 Cytherella paramuensteri Swain & Peterson

Foraminifera
1 Vaginulina mecyna Loeblich & Tappan

Section 16. Cody, Wyoming.

Samples C3, 7-9, 15, 18, 20, 24, 27, 28, 30, 31, 33 and 34 yielded no microfossils.

Sample C32.

Ostracoda
2 Aparchitocythere loeblichorum Swain & Peterson
3 A. typica Swain & Peterson

Sample C26.

Ostracoda
16 Aparchitocythere typica Swain & Peterson
1 Cytherura lanceolata Swain & Peterson

Sample C16.

Ostracoda
2 Procytheridea exempla Peterson

Sample C13.

Ostracoda
70 Procytheridea exempla Peterson
4 P. crassa Peterson

4	Paracypris projecta Peterson
1	Monoceratina pararossae Peterson
1	Cytherelloidea recurvata Peterson
	Foraminifera
8	Lenticulina cf. L. audax Loeblich & Tappan
1	Dentalina polyholca Loeblich & Tappan
1	D. gracilistriata Loeblich & Tappan
3	Citharina entypomatus Loeblich & Tappan
2	C. latissima Loeblich & Tappan
13	Astacolus ectypus Loeblich & Tappan
4	A. petalus Loeblich & Tappan
4	Citharinella compara Loeblich & Tappan
2	C. latifolia Loeblich & Tappan
1	Dentalina leptosyna Loeblich & Tappan
8	Vaginulinopsis eritheles Loeblich & Tappan

Sample C12.

	Ostracoda
13	Procytheridea exempla Peterson
2	Paracypris projecta Peterson
	Foraminifera
74	Lenticulina cf. L. audax Loeblich & Tappan
4	L. dilecta Loeblich & Tappan
1	Dentalina gracilistriata Loeblich & Tappan
3	D. ectadia Loeblich & Tappan
2	Citharinella compara Loeblich & Tappan
2	Citharina entypomatus Loeblich & Tappan
1	C. latissima Loeblich & Tappan
8	Astacolus petalus Loeblich & Tappan
19	A. ectypus Loeblich & Tappan
2	Vaginulinopsis eritheles Loeblich & Tappan
1	Marginulinopsis phragmites Loeblich & Tappan
2	Vaginalina mecyna Loeblich & Tappan
1	Vaginulinopsis sp.

Sample C11.

	Ostracoda
1	Procytheridea crassa Peterson
7	P. exempla Peterson
6	Paracypris projecta Peterson
1	Monoceratina pararossae Peterson
1	Cytherella paramuensteri Swain & Peterson
	Foraminifera
200	Lenticulina cf. L. audax Loeblich & Tappan
13	L. dilecta Loeblich & Tappan

4	Citharina entypomatus Loeblich & Tappan
1	C. latissima Loeblich & Tappan
11	Astacolus ectypus Loeblich & Tappan
8	A. agalmatus Loeblich & Tappan
2	A. petalus Loeblich & Tappan
1	Dentalina ectadia Loeblich & Tappan
2	Vaginulinopsis eritheles Loeblich & Tappan
1	Vaginulina mecyna Loeblich & Tappan
2	V. compsa Loeblich & Tappan
1	Marginulinopsis phragmites Loeblich & Tappan

Sample C10.

Ostracoda

3	Procytheridea exempla Peterson
3	Paracypris projecta Peterson
1	Monoceratina pararossae Peterson

Foraminifera

7	Astacolus ectypus Loeblich & Tappan
4	Lenticulina dilecta Loeblich & Tappan
59	L. cf. L. audax Loeblich & Tappan
1	Citharina entypomatus Loeblich & Tappan
2	Marginulinopsis phragmites Loeblich & Tappan
1	Citharinella compara Loeblich & Tappan
1	Dentalina ectadia Loeblich & Tappan
1	Vaginulina compsa Loeblich & Tappan

Section 8. Freezeout Mountains, Wyoming.

Samples FM 4, 8, 13, 23, 24, 26, 28, 29, yielded no microfossils.

Sample FM27.

Foraminifera

3	Ammomarginulina baryntica Loeblich & Tappan

Sample FM25.

Foraminifera

127	Lenticulina audax Loeblich & Tappan
12	Astacolus agalmatus Loeblich & Tappan
1	Ammobaculites cobbani Loeblich & Tappan
1	Dentalina ectadia Loeblich & Tappan
1	Citharinella exarata Loeblich & Tappan

Section 13. Alcova, Wyoming.

Samples A9, 10, 20, 23, 29, 31 yielded no microfossils.

Sample A34.

Ostracoda

44 Aparchitocythere typica Swain & Peterson
7 Cytherella paramuensteri Swain & Peterson
1 C. ventropleura Swain & Peterson
2 Leptocythere imlayi Swain & Peterson

Foraminifera

1 Dentalina ectadia Loeblich & Tappan
1 D. leptosyna Loeblich & Tappan
7 Reophax sundancensis Loeblich & Tappan
15 Ammobaculites imlayi Loeblich & Tappan
1 Lenticulina cf. L. audax Loeblich & Tappan
2 Vaginulina sp.
1 Citharinella sp.

Sample A28.

Foraminifera

18 Ammomarginulina baryntica Loeblich & Tappan
22 Ammobaculites cobbani Loeblich & Tappan
15 A. imlayi Loeblich & Tappan
1 A. venustus Loeblich & Tappan
4 Reophax sundancensis Loeblich & Tappan

Sample A27.

Foraminifera

28 Ammobaculites cobbani Loeblich & Tappan
24 Ammomarginulina baryntica Loeblich & Tappan

Sample A26.

Foraminifera

6 Ammobaculites cobbani Loeblich & Tappan
11 Ammomarginulina baryntica Loeblich & Tappan

Sample A25.

Foraminifera

11 Ammobaculites cobbani Loeblich & Tappan
3 Ammomarginulina baryntica Loeblich & Tappan

Sample A24.

Foraminifera

33 Ammomarginulina baryntica Loeblich & Tappan
17 Ammobaculites cobbani Loeblich & Tappan
1 A. imlayi Loeblich & Tappan

Sample A8.

Ostracoda

3 Aparchitocythere compressa Peterson
14 A. elongata Peterson
5 Cytherella paramuensteri Swain & Peterson

Sample A7

	Ostracoda
17	Aparchitocythere compressa Peterson
2	A. elongata Peterson
150+	Cytherella paramuensteri Swain & Peterson
	Foraminifera
3	Lenticulina cf. L. audax Loeblich & Tappan
2	Vaginulina sp.
1	Vaginulinopsis eritheles Loeblich & Tappan

Sample A6.

	Ostracoda
122	Aparchitocythere compressa Peterson
7	A. elongata Peterson
140	Cytherella paramuensteri Swain & Peterson

Sample A5.

	Ostracoda
19	Aparchitocythere compressa Peterson
3	A. elongata Peterson
39	Cytherella paramuensteri Swain & Peterson

Sample A4.

	Ostracoda
72	Aparchitocythere compressa Peterson
7	A. elongata Peterson
32	Cytherella paramuensteri Swain & Peterson

Section 12. Vinceants Ranch, Lander, Wyoming.

Samples V5, 6, 12, 24-26 yielded no microfossils.

Sample V33.

	Ostracoda
25	Aparchitocythere typica Swain & Peterson
5	A. loeblichorum Swain & Peterson
1	Cytherella paramuensteri Swain & Peterson
1	Leptocythere imlayi Swain & Peterson
	Foraminifera
1	Lenticulina audax Loeblich & Tappan

Sample V29.

	Ostracoda
1	Aparchitocythere loeblichorum Swain & Peterson
1	A. typica Swain & Peterson
1	Cythereis zygoventralis Swain & Peterson

Foraminifera

1 Citharinella sp.

Sample V28.

Ostracoda

23 Aparchitocythere typica Swain & Peterson
1 Cytherura lanceolata Swain & Peterson
4 Cythereis zygoventralis Swain & Peterson

Foraminifera

8 Lenticulina audax Loeblich & Tappan
1 Vaginulina compsa Loeblich & Tappan
2 Astacolus agalmatus Loeblich & Tappan

Sample V27.

Ostracoda

16 Cytherella paramuensteri Swain & Peterson
3 Aparchitocythere typica Swain & Peterson
3 Cytherura lanceolata Swain & Peterson
3 Monoceratina sundancensis Swain & Peterson
2 Cythereis zygoventralis Swain & Peterson

Foraminifera

7 Lenticulina audax Loeblich & Tappan
3 Citharina entypomatus Loeblich & Tappan
2 Citharinella exarata Loeblich & Tappan
8 Astacolus agalmatus Loeblich & Tappan
1 Reophax sundancensis Loeblich & Tappan

Sample V23.

Foraminifera

3 Lenticulina audax Loeblich & Tappan
18 Ammobaculites imlayi Loeblich & Tappan
8 A. cobbani Loeblich & Tappan
2 Citharina entypomatus Loeblich & Tappan
1 Dentalina leptosyna Loeblich & Tappan
1 Massilina sp.
2 Astacolus agalmatus Loeblich & Tappan
1 Vaginulinopsis epicharis Loeblich & Tappan

Sample V22.

Ostracoda

1 Aparchitocythere typica Swain & Peterson
1 Cythereis zygoventralis Swain & Peterson

Foraminifera

1 Ammobaculites imlayi Loeblich & Tappan
1 Astacolus agalmatus Loeblich & Tappan

Sample V21.

Ostracoda

1 Aparchitocythere loeblichorum Swain & Peterson

Foraminifera

1 Citharinella rhomboidea Loeblich & Tappan
2 Ammobaculites cobbani Loeblich & Tappan
1 Citharina entypomatus Loeblich & Tappan
3 Lenticulina audax Loeblich & Tappan
2 Astacolus agalmatus Loeblich & Tappan

Sample V18.

Ostracoda

1 Cytherella paramuensteri Swain & Peterson
1 Monoceratina sundancensis Swain & Peterson
10 Aparchitocythere typica Swain & Peterson

Foraminifera

50 Lenticulina audax Loeblich & Tappan
8 Citharina entypomatus Loeblich & Tappan
3 Astacolus agalmatus Loeblich & Tappan
1 Vaginulina compsa Loeblich & Tappan
1 Vaginulinopsis epicharis Loeblich & Tappan
1 Massilina sp.

Sample V17.

Ostracoda

1 Cytherelloidea recurvata Peterson
5 Aparchitocythere typica Swain & Peterson

Foraminifera

1 Ammomarginulina baryntica Loeblich & Tappan
3 Citharina entypomatus Loeblich & Tappan

Sample V16.

Ostracoda

10 Aparchitocythere typica Swain & Peterson
1 Cytherura lanceolata Swain & Peterson
1 Monoceratina sundancensis Swain & Peterson

Foraminifera

6 Lenticulina audax Loeblich & Tappan
7 Ammobaculites cobbani Loeblich & Tappan
19 Ammomarginulina baryntica Loeblich & Tappan
3 Citharina entypomatus Loeblich & Tappan
1 Astacolus agalmatus Loeblich & Tappan

Sample V15.

Foraminifera

85	Lenticulina audax Loeblich & Tappan
1	Nodasaria lirulata Loeblich & Tappan
1	Citharina entypomatus Loeblich & Tappan
1	Astacolus agalmatus Loeblich & Tappan
1	Frondicularia sp.

Sample V3.

	Ostracoda
5	Aparchitocythere compressa Peterson
5	Cytherella paramuensteri Swain & Peterson

Sample V2.

	Ostracoda
22	Aparchitocythere compressa Peterson
3	Cytherella paramuensteri Swain & Peterson

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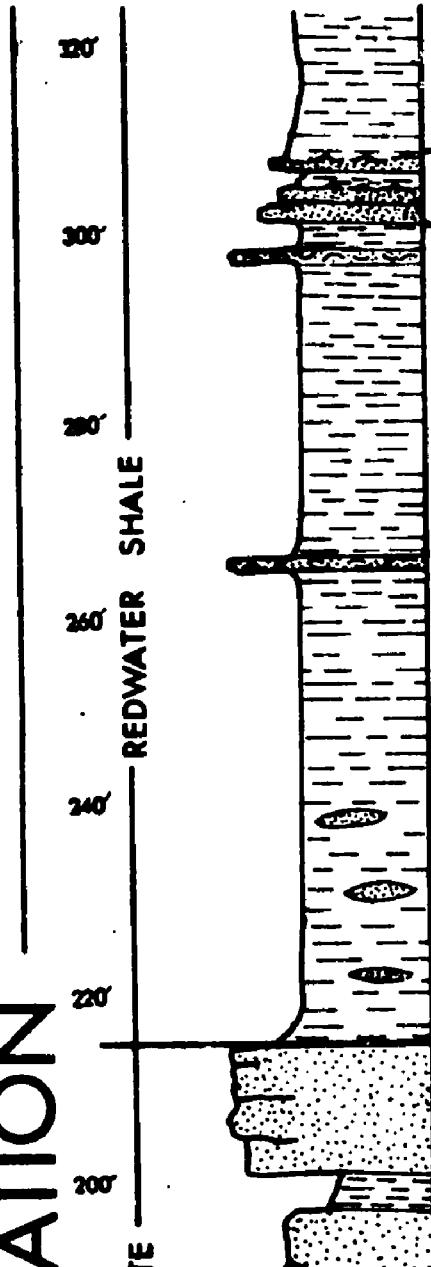
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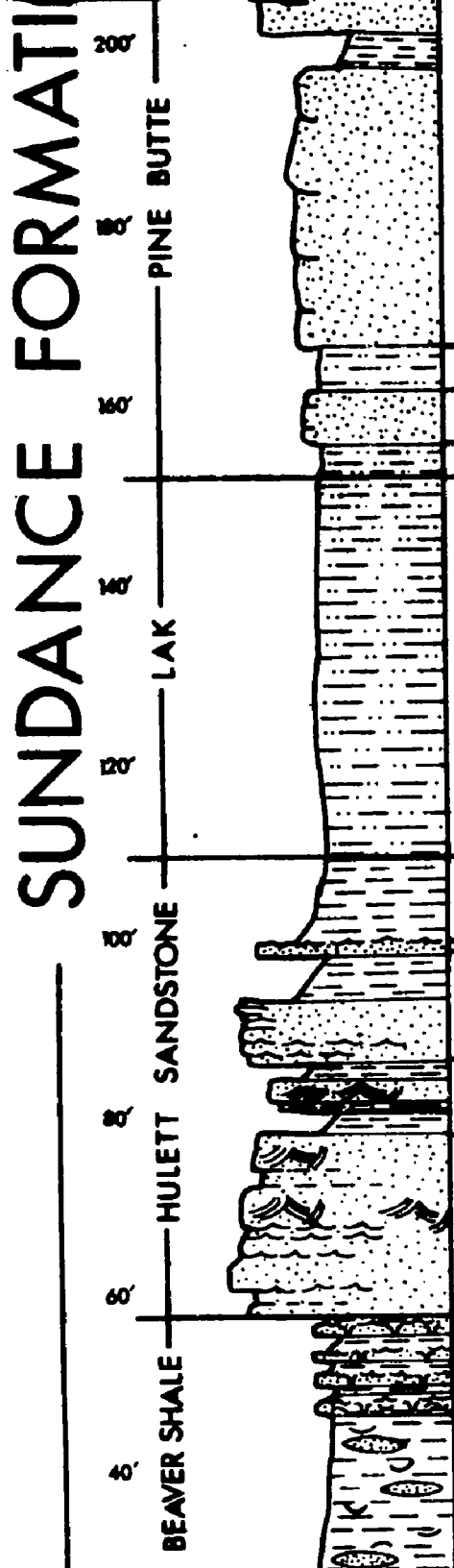
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NEWCASTLE

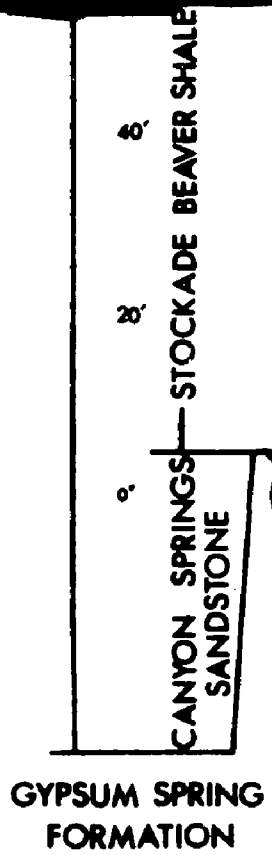
(appendix 4 and 5 lists bivalves and microfossils for samples given at right of section.)



		Ft.	In.
N48	Shale, light greenish-gray, very calcareous, soft, unconsolidated.	5	0
N47	Shale, dark-gray, hard	9	5
	Shale, medium-gray, hard, interbeds of brown thin-bedded symmetrically ripple-marked sandstone	13	1
N45	Sandstone, light olive-gray, calcareous, very fine-grained, glauconitic, packed with oyster shells and fragments	1	6
N44	Shale, medium-gray to greenish-gray, silty, soft, unconsolidated.	31	8
N43			
N42	Sandstone, light olive-gray, calcareous, very fine-grained, glauconitic, packed with oyster shells and echinoderm fragments.	1	3
N41			
N40			
N39	Shale, medium-to-dark-gray, soft, sandy in lower part	50	0
	Thickness of Redwater Shale .	111	11
N38			
	Sandstone, yellowish-white, calcareous, fine-grained, medium-bedded, ledge-forming	12	0
N36	Shale, medium-gray, sandy, soft	5	5



N36	Shale, medium-gray, sandy, soft	5	5
	Sandstone, white, medium-to-fine-grained, well sorted, soft	27	6
	Siltstone, reddish-brown	5	0
	Sandstone, light-brown, fine-grained, calcareous, soft, some greenish-gray shale	5	8
	Siltstone, greenish-gray, sandy	4	5
	Thickness of Pine Butte	60	0
	Siltstone, salmon-red, soft, upper 5 inches is greenish-gray shale	43	11
	Thickness of Lak	43	11
N25	Shale, greenish-gray, sandy, soft	8	8
N24			
N22	Sandstone, white, very fine-grained, calcareous, symmetrically ripple-marked	0	2
	Shale, greenish-gray, sandy, soft	1	3
N20	Sandstone, white, fine-to-medium-grained, calcareous, symmetrically ripple-marked, thin shale partings	7	10
	Sandstone, light-gray, calcareous, medium-grained, cross-bedded, light-gray sandy limestone at base, green, gray and maroon shale below limestone	10	8
	Sandstone, white, calcareous, very fine-grained, medium-bedded, cross-bedded, symmetrically ripple-marked, thin grayish-green shale partings	21	0
	Thickness of Hulett Sandstone	55	4
	Shale, greenish-gray, soft, interbeds of light-brown calcareous very fine-grained ripple-marked burrowed sandstone	11	11
N12	Siltstone, light olive-gray, calcareous, symmetrically ripple-marked, burrowed, bivalves	0	3
N11			
N10	Shale, medium-gray, soft, sandy in spots, bivalves	30	0
N9			



	Shale, greenish-gray, soft, interbeds of light-brown calcareous very fine-grained ripple-marked burrowed sandstone	11	11
N12	Siltstone, light olive-gray, calcareous, symmetrically ripple-marked, burrowed, bivalves	0	3
N11			
N10	Shale, medium-gray, soft, sandy in spots, bivalves	30	0
N9			
N8			
N7			
N6			
N5	Siltstone, light olive-gray, sandy, bivalves	0	10
N4	Shale, light olive-gray, calcareous, fossiliferous lime nodules.	11	7
N3	Thickness of Stockade Beaver Shale .	53	9
N2	Sandstone, very light-gray, calcareous, very fine-grained, iron stained on top, oyster shells and fragments underlain by gypsum of Gypsum Spring Formation	1	0
	Total thickness of section .	325	11

LEGEND

LIMESTONE

CLAYSTONE OR SHALE

SILTSTONE

SANDSTONE

GLAUCONITE

CHERT PEBBLES

OOLITES

PELLETS

LIME NODULES

CRINOID COLUMNALS

ECHINODERM FRAGMENTS

BRYOZOA

BIVALVES

CORAL

BRACHIOPODS

RIPPLE MARKS

CROSS BEDDING

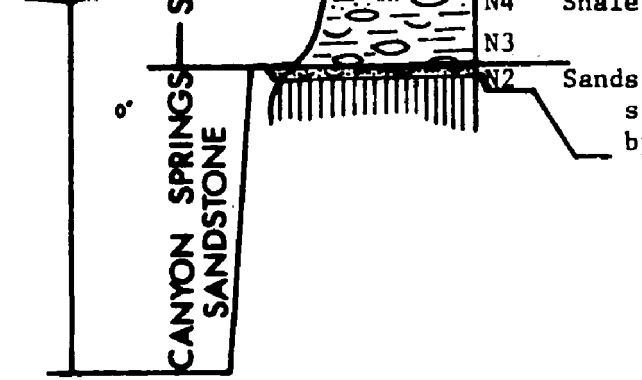
BURROWS

BORED SURFACE

TRAIL MARKS

BORED COBBLES

IRON NODULES



GYPSUM SPRING FORMATION

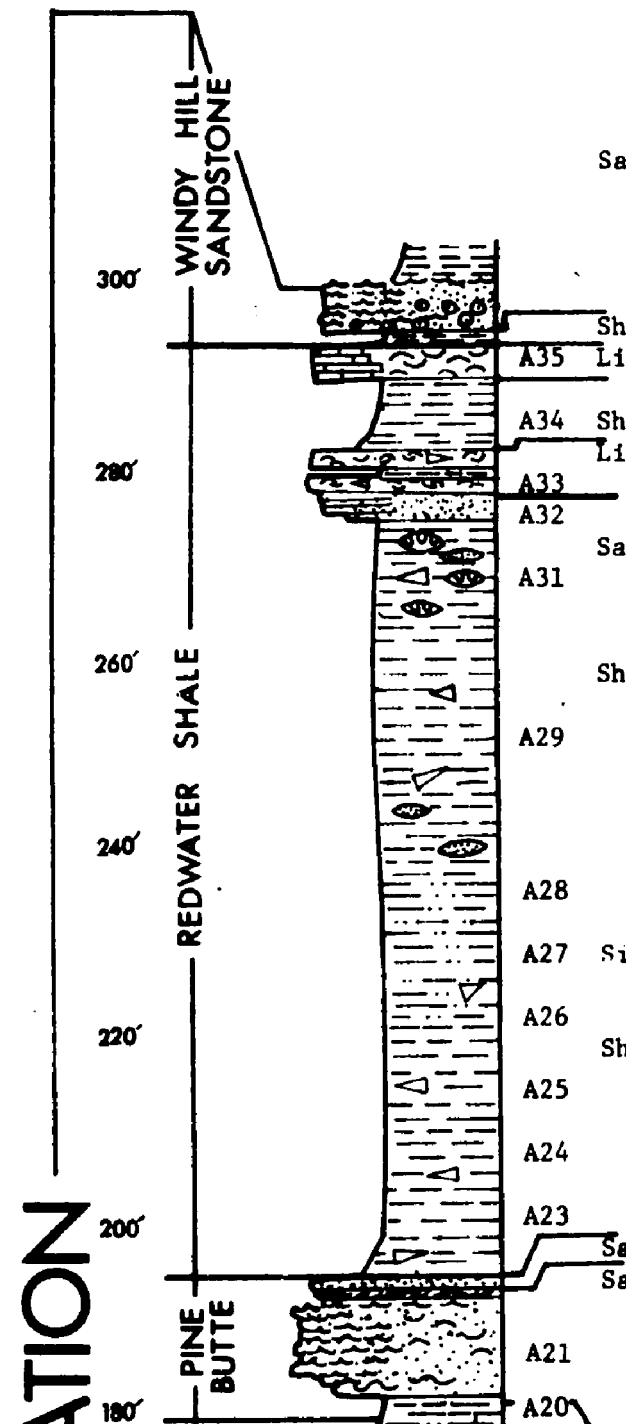
N4	Shale, light olive-gray, calcareous, fossiliferous lime nodules.	11	7
N3	Thickness of Stockade Beaver Shale .	53	9
N2	Sandstone, very light-gray, calcareous, very fine-grained, iron stained on top, oyster shells and fragments underlain by gypsum of Gypsum Spring Formation	1	0
	Total thickness of section .	325	11

LEGEND

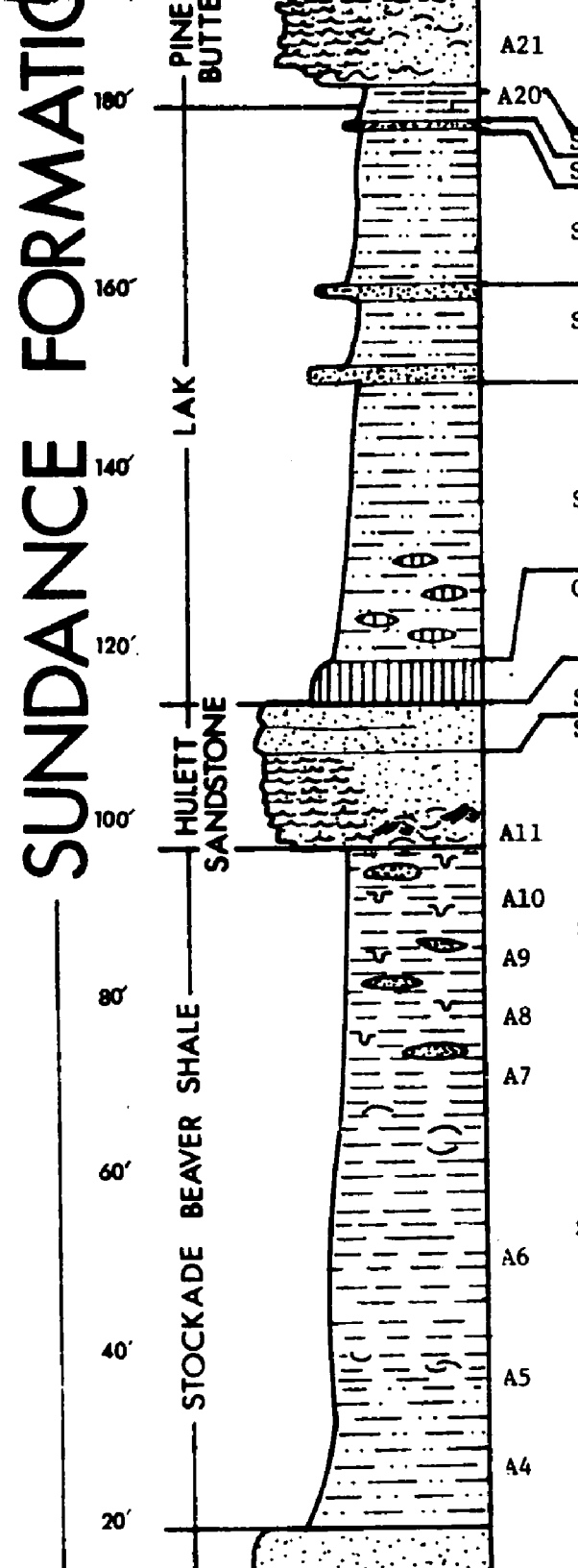
- LIMESTONE
- CLAYSTONE OR SHALE
- SILTSTONE
- SANDSTONE
- GYPSUM
- GLAUCONITE
- CHERT PEBBLES
- OOLITES
- PELLETS
- LIME NODULES
- CRINOID COLUMNALS
- ECHINODERM FRAGMENTS
- BRYOZOA
- BIVALVES
- GASTROPODS
- BELEMNITES
- CORAL
- BRACHIOPODS
- RIPPLE MARKS
- CROSS BEDDING
- BURROWS
- BORED SURFACE
- TRAIL MARKS
- BORED COBBLES
- IRON NODULES
- BRECCIA
- VUGGY

PLATE 13

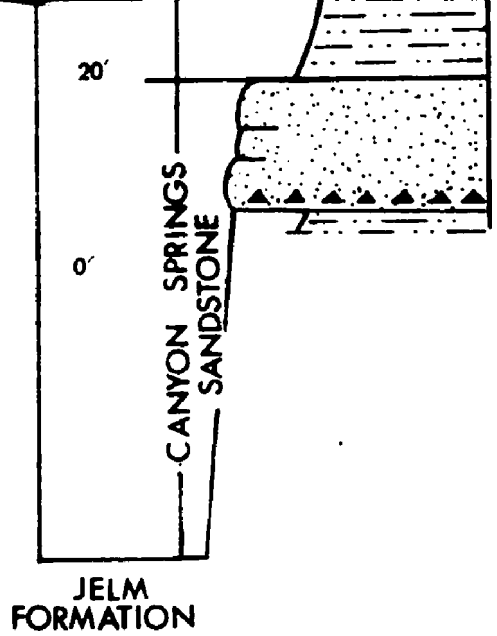
ALCOVA



		Ft.	In.
	Sandstone, grayish-tan, medium-grained, calcareous, interference ripple-marks in upper 3 feet, symmetrical ripple marks and oolites in lower 3 feet, overlain by gray shale of Morrison Formation	5	8
	Thickness of Windy Hill Sandstone	5	8
	Shale, dark-gray, soft	1	0
A35	Limestone, pale yellowish-brown, crystalline, bivalves	2	6
A34	Shale, dark-gray, calcareous, soft	9	0
A33	Limestone, light-gray, silty, platy, crystalline, packed with bivalves and belemnites, interbeds of tan sandstone	5	0
A32			
A31	Sandstone, light-tan, fine-grained, calcareous, silty, thin-bedded	3	2
A29	Shale, dark-gray, soft, sandy near top and bottom, bored limestone cobbles with oyster spats near top, belemnites	39	0
A28			
A27	Siltstone, dark-gray, soft, shaly, belemnites	16	0
A26			
	Shale, dark-gray, calcareous, soft, belemnites	24	0
A25	Thickness of Redwater Shale	99	8
A24			
A23			
	Sandstone, white, calcareous, very fine-grained, cross-bedded	3	10
	Sandstone, yellowish-gray, calcareous, fine-grained, thin-bedded, symmetrically ripple-marked, centrally furrowed trail-marks in lower 3 feet, bivalves 4 feet above base, thin beds of gray shale at base	10	8
A21			
A20	Thickness of Pine Butte	14	6



symmetrically ripple-marked, centrally furrowed trail-marks in lower 3 feet, bivalves 4 feet above base, thin beds of gray shale at base	10	8
Thickness of Pine Butte .	14	6
Siltstone, salmon-red, calcareous, soft	3	8
Sandstone, white, calcareous, very fine-grained	1	10
Siltstone, salmon-red, calcareous, soft	22	0
Siltstone, salmon-red, calcareous, soft, interbeds of white fine-grained sandstone	10	11
Siltstone, salmon-red, soft, gypsum in lower 16 feet	30	0
Gypsum, white, soft	4	0
Thickness of Lak .	72	5
Sandstone, white, calcareous, fine-grained, thick-bedded	5	6
Sandstone, light yellowish-gray, calcareous, fine-grained, thin-bedded, ripple-marked, cross-bedded, bivalves	9	2
Thickness of Hulett Sandstone .	14	8
Shale, greenish-gray, calcareous, sandy, burrowed	21	6
Shale, light olive-gray, calcareous, soft, bivalves	42	8
Siltstone, medium-gray, calcareous, hard	15	0
Thickness of Stockade Beaver Shale .	79	2



A4	Siltstone, medium-gray, calcareous, hard	15	0
	Thickness of Stockade Beaver Shale .	79	2
	Sandstone, light yellowish-gray, calcareous, medium-grained, massive-bedded, chert pebbles scattered in 1 foot band at base, underlain by red siltstone of Jelm Formation	14	0
	Thickness of Canyon Springs Sandstone ..	14	0
	Total thickness of section .	300	1

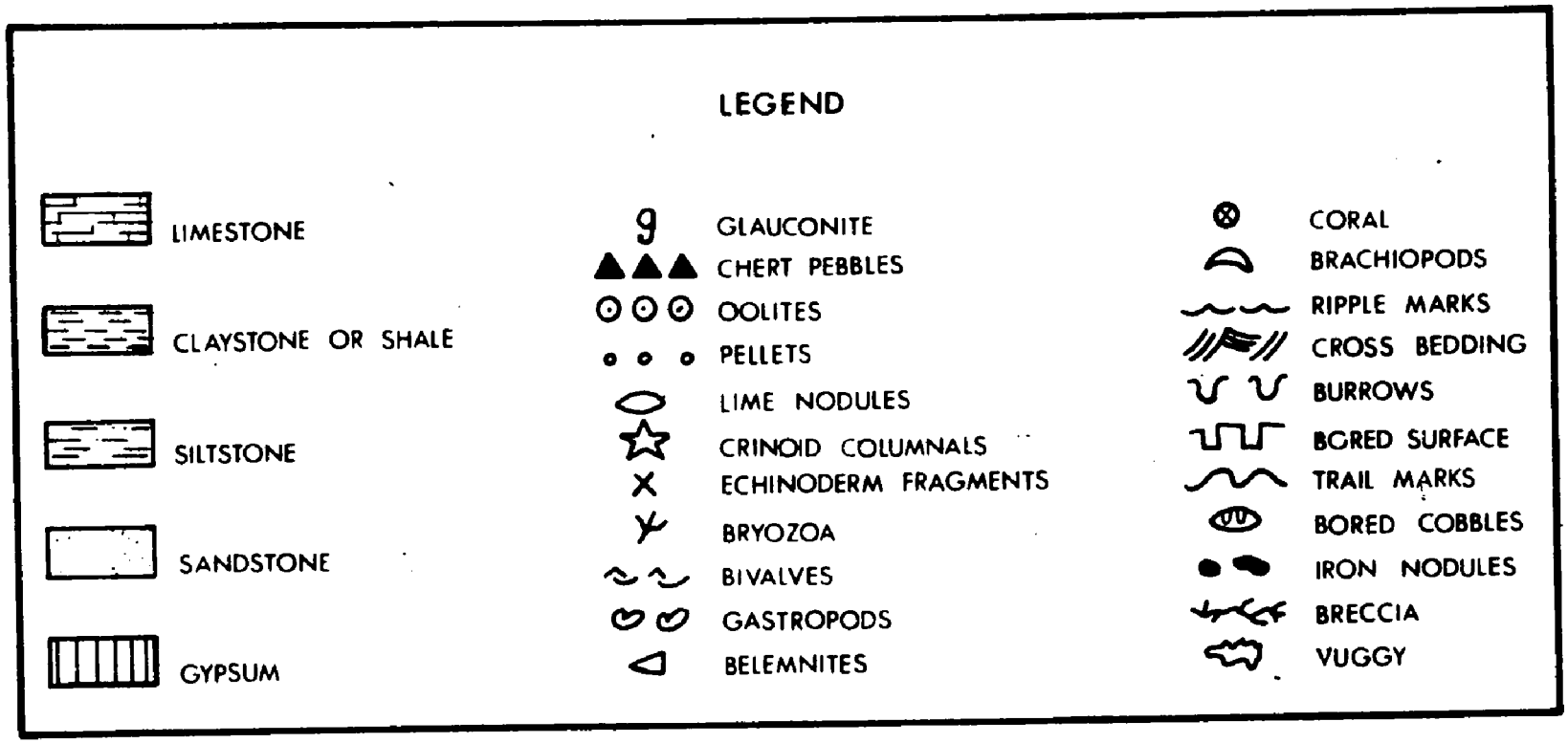
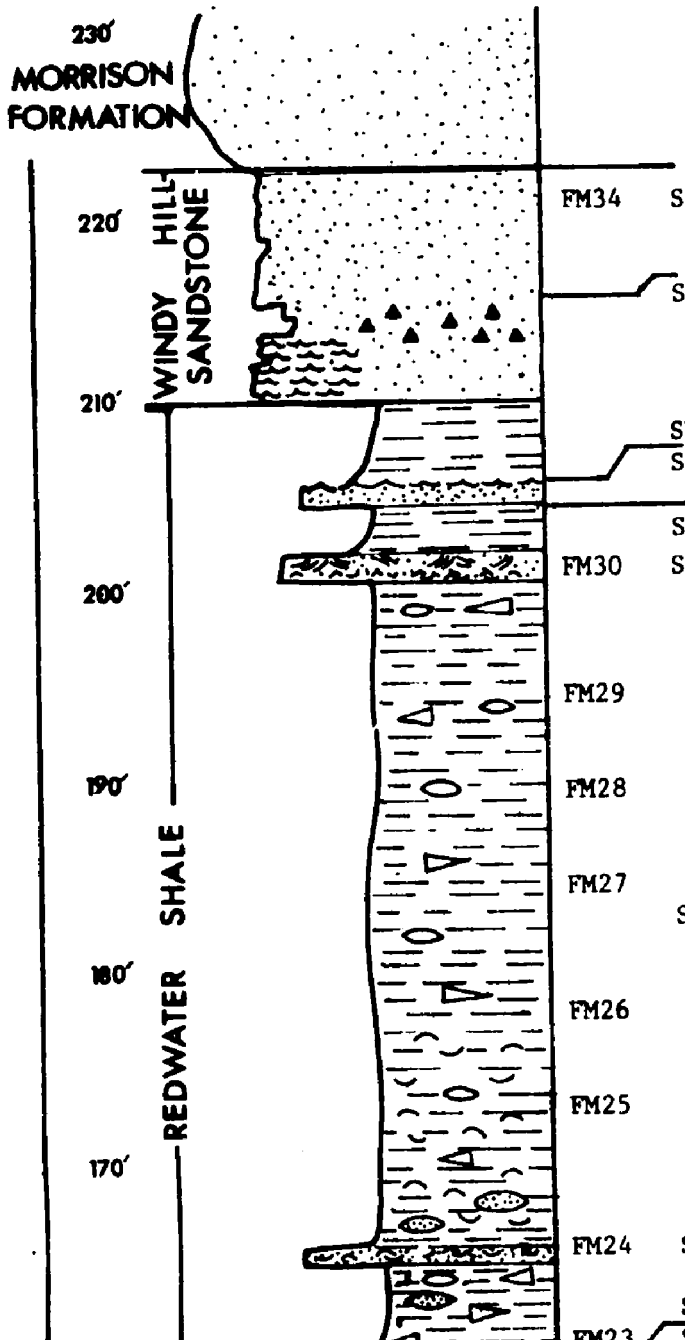
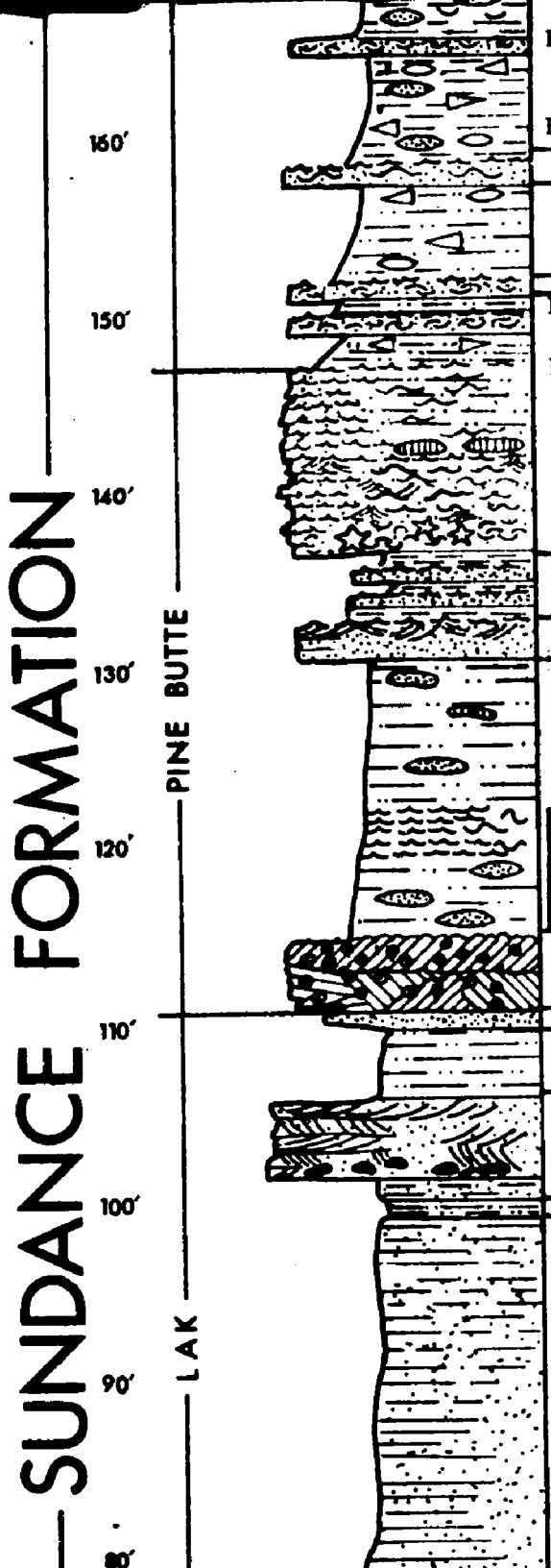


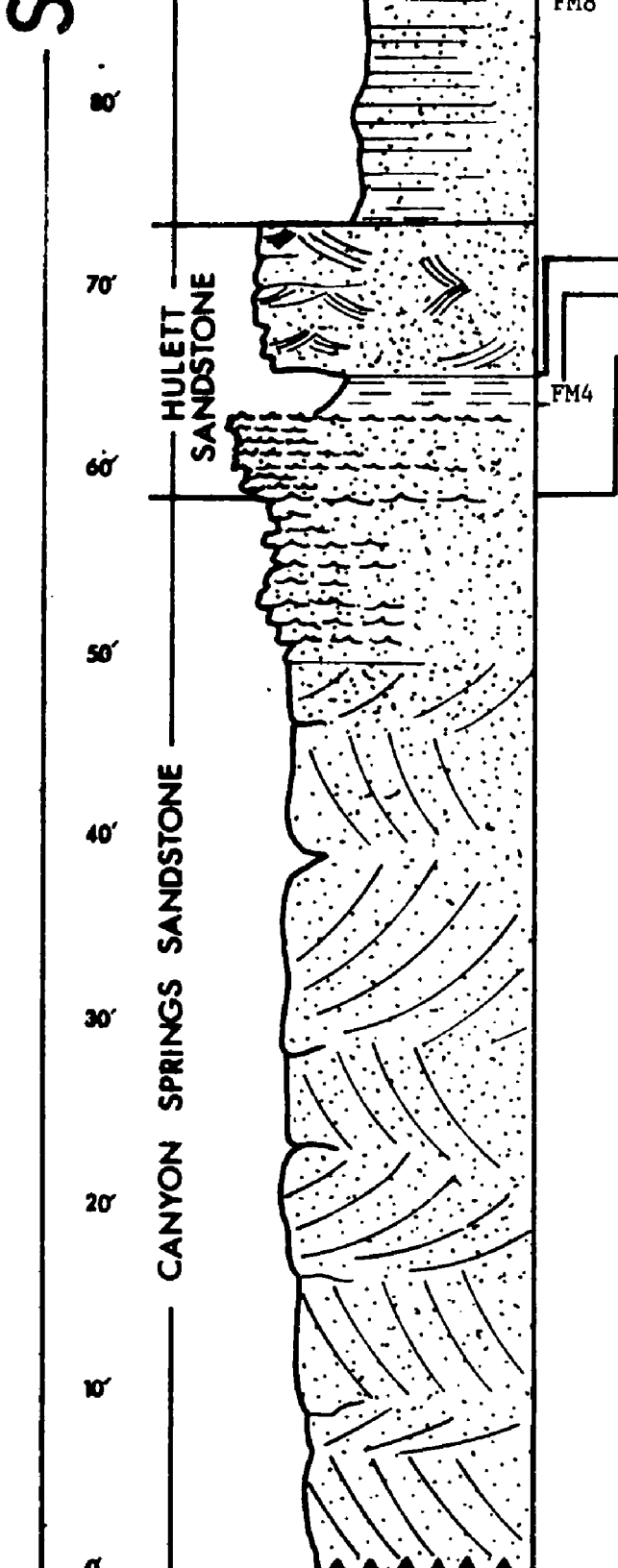
PLATE 14



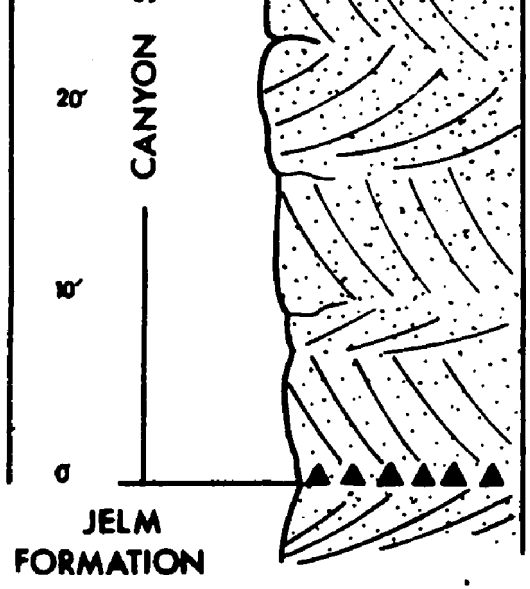
		Ft.	In.
FM34	Sandstone, light-brown, fine-grained, calcareous, soft, thin-bedded, chert pebbles at base, overlain by lenticular sandstone of Morrison Formation	8	0
	Sandstone, light-yellow, very fine-grained, calcareous, thin-bedded, symmetrically ripple-marked	3	7
	Thickness of Windy Hill Sandstone.	11	7
	Shale, dark-gray, soft	3	7
	Sandstone, medium-gray, calcareous, very fine-grained, interferrence ripple-marks	1	0
	Shale, dark-gray, soft	2	10
FM30	Sandstone, medium-gray, calcareous, very fine-grained, glauconitic, thin-bedded, cross-bedded, bivalves, oyster coquina at base	1	2
FM29			
FM28			
FM27	Shale, medium-to-dark-gray, lime nodules, bivalves in lower 12 feet, sandy in lower 6 feet, belemnites	34	0
FM26			
FM25			
FM24	Sandstone, light olive-gray, calcareous, very fine-grained glauconitic, bivalves, oyster coquina at base		8
	Shale, dark-gray, calcareous, sandy, lime nodules, belemnites.	6	8
FM23	Sandstone, grayish-brown, calcareous, fine-grained, inter-		



FM24	Sandstone, light olive-gray, calcareous, very fine-grained glauconitic, bivalves, oyster coquina at base	8
	Shale, dark-gray, calcareous, sandy, lime nodules, belemnites.	6 8
FM23	Sandstone, grayish-brown, calcareous, fine-grained, interferrence ripple-marks, centrally furrowed trail marks...	7
	Siltstone, medium-gray, soft, lime nodules	5 3
	Sandstone, yellowish-gray, calcareous, very fine-grained glauconitic , interferrence ripple-marks, bivalves	4
	Siltstone, medium-gray lime nodules, belemnites	1 7
FM22	Sandstone, yellowish-gray, calcareous, very fine-grained, ripple-marked, bivalves, belemnites, underlain by	
FM21	siltstone	3 10
	Thickness of Redwater Shale .	81 6
	Sandstone, light-gray, calcareous, fine-grained, thin-bedded, ripple-marked, centrally furrowed trail-marks, cross-bedded in lower half, gypsiferous; crinoid and oyster fragments in lower foot	10 8
	Shale, medium-gray, sandy, interbeds of greenish-gray symmetrically rippled sandstone	2 8
	Sandstone, light-gray, calcareous, very fine-grained, symmetrically ripple-marked, cross-bedded	1 10
	Siltstone, maroon, calcareous, sandy, symmetrically ripple-marked and centrally furrowed trail-marks near middle, interbeds of greenish-gray shale in lower part	15 5
	Sandstone, light-gray, calcareous, fine-grained, oolitic, festoon cross-bedded throughout	3 8
	Thickness of Pine Butte .	34 3
FM13		
	Sandstone, light-gray, calcareous, fine-grained, thin shale partings	1 0
	Siltstone, light-red, calcareous, soft	4 0
	Sandstone, light-gray, red-specked, calcareous, fine-grained, glauconitic, medium-bedded, cross-bedded, iron nodules ..	3 8
	Siltstone, light reddish-brown, calcareous	2 8
	Sandstone, light-gray, calcareous,fine-grained, soft	25 10
	Thickness of Lak .	36 4
FM8		



Sandstone, light-gray, calcareous, medium-grained, soft, medium-bedded, cross-bedded	8	0
Shale, dark-gray, hard	1	0
Sandstone, light-yellow, calcareous, fine-grained ripple-marked	4	0
Thickness of Hulett Sandstone .	13	0
Sandstone, yellowish-white, coarse-grained, thin-bedded, ripple-marked	8	0
Sandstone, yellowish-white, medium-grained, massive-bedded, cross-bedded, stringers of chert pebbles at base, underlain by massive white sandstone of Jelm Formation ...	54	0
Thickness of Canyon Springs Sandstone .	62	0
Total thickness of section .	238	8



LEGEND

LIMESTONE

CLAYSTONE OR SHALE

SILTSTONE

SANDSTONE

GYPSUM

GLAUCONITE

CHERT PEBBLES

OOLITES

PELLETS

LIME NODULES

CRINOID COLUMNALS

ECHINODERM FRAGMENTS

BRYOZOA

BIVALVES

GASTROPODS

BELEMNITES

CORAL

BRACHIOPODS

RIPPLE MARKS

CROSS BEDDING

BURROWS

BORED SURFACE

TRAIL MARKS

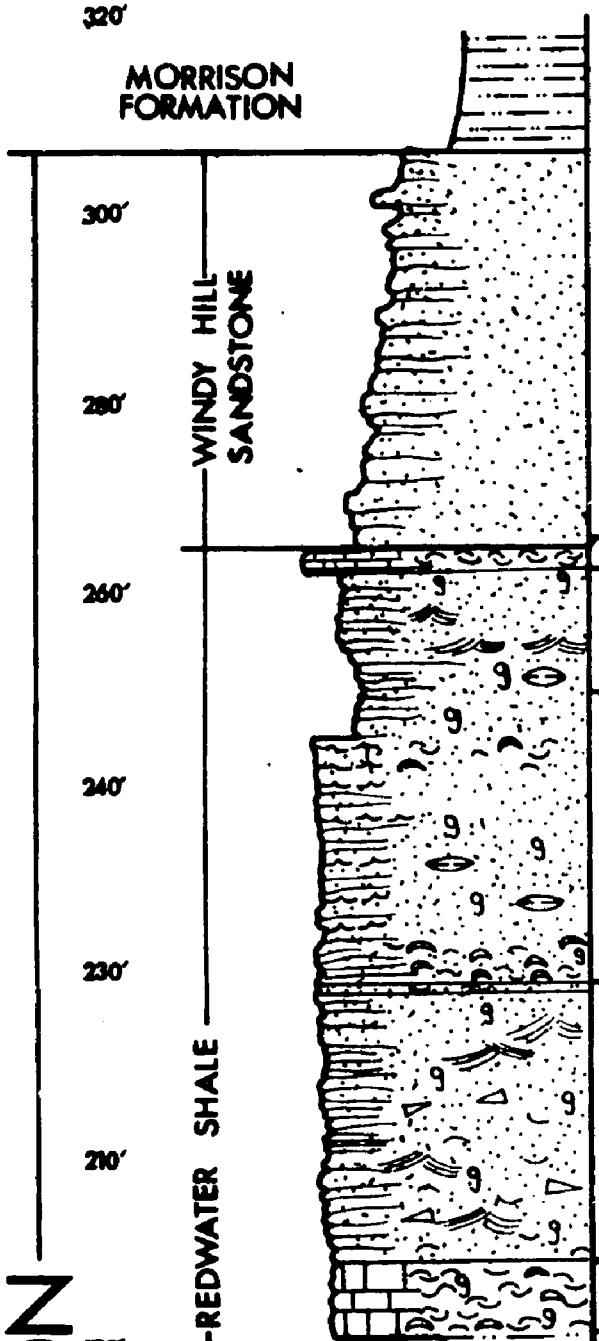
BORED COBBLES

IRON NODULES

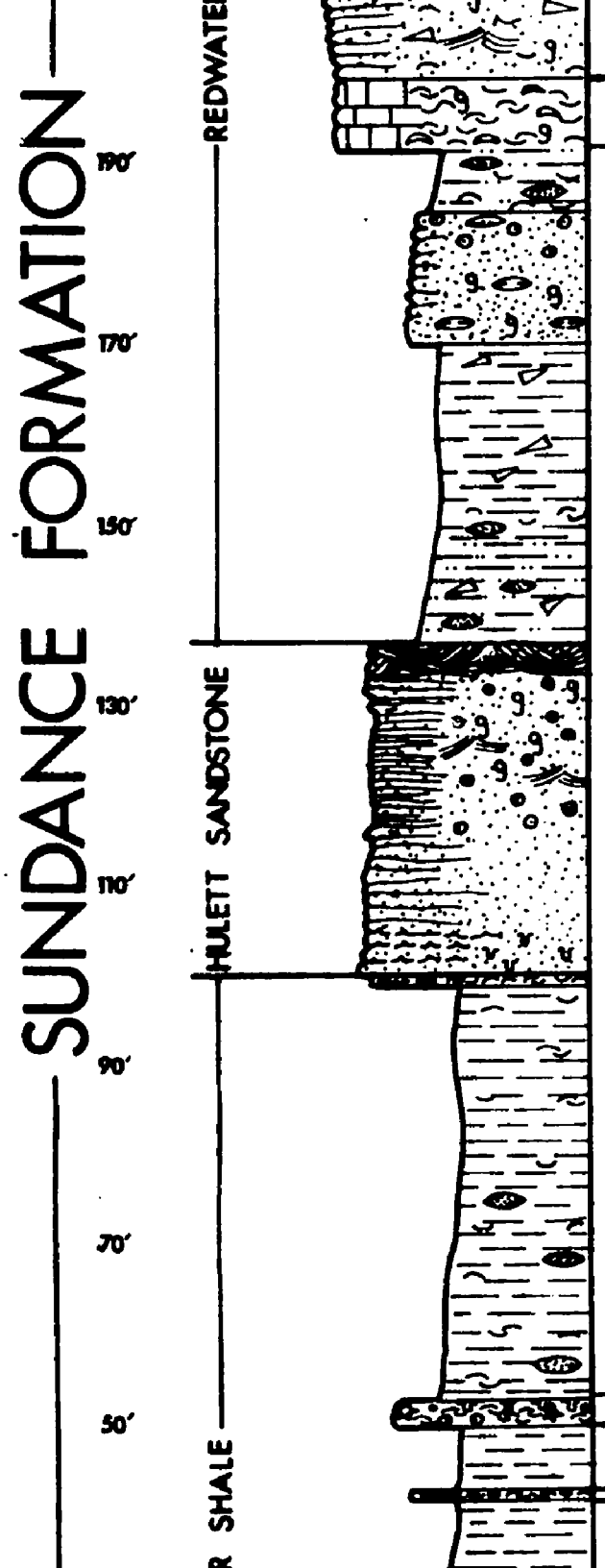
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VUGGY

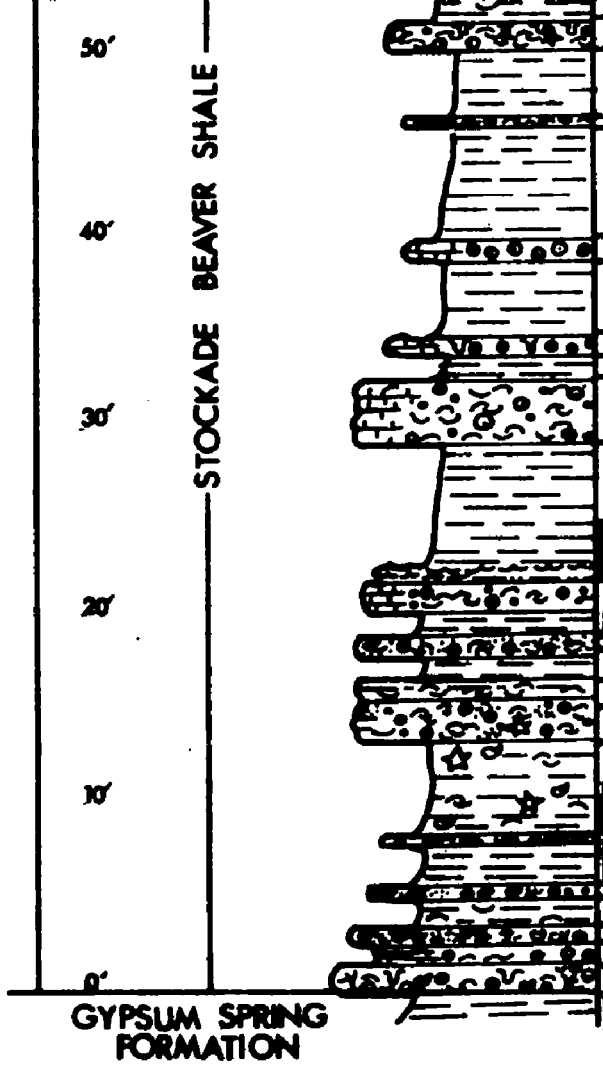
MAVERICK SPRING



	Ft.	In
Sandstone, grayish-white, calcareous, very fine-grained, medium-bedded, soft; overlain by salmon-red silt-stone of Morrison	40	8
Thickness of Windy Hill Sandstone .	40	8
Limestone, very light-gray, crystalline, sandy, glauconitic, packed with bivalves	1	8
Sandstone, brownish-green, medium-grained, glauconitic, thin-bedded, cross-bedded in top-half, soft, shaly	25	1
Sandstone, very light-gray, greenish-gray in spots, fine-to-medium-grained, calcareous, glauconitic, thin-bedded, shaly in spots, symmetrically ripple-marked, bivalves, brachiopods	36	7
Sandstone, light brownish-gray, calcareous, glauconitic, fine-grained in top 7 feet, coarse-grained in lower 18 feet, thin-bedded, cross-bedded, oyster shells and belemnites in lower half	24	11
Limestone, yellowish-gray, coarsely-crystalline, glauconitic, medium-bedded, brachiopods, oysters	7	0



	Limestone, yellowish-gray, coarsely-crystalline, glauconitic,		
Ms46	medium-bedded, brachiopods, oysters	7	0
	Siltstone, yellowish-gray, sandy, calcareous, bivalves	8	6
Ms45			
	Sandstone, medium-brown, very fine-grained, medium-bedded, glauconitic in lower 11 feet, oolitic at top, shaly and slope forming	15	0
Ms41	Shale, medium-gray, sandy, hard, belemnites	18	8
Ms40			
Ms39	Siltstone, yellowish-gray, sandy, calcareous, belemnites, oysters		
Ms38	4 feet from top	15	8
Ms37	Thickness of Redwater Shale .	153	1
Ms36	Sandstone, light-tan, calcareous, fine-to-medium-grained, thin- to medium-bedded, ripple-marked and burrowed at bottom, oolitic near top, cross-bedded, glauconitic in top half, festoon cross-beds at top	38	5
	Thickness of Hulett Sandstone .	38	5
Ms29			
Ms28			
Ms27			
Ms26			
Ms25			
Ms24			
Ms23	Shale, light olive-gray, calcareous, sandy in spots, bivalves		
Ms22	(packed at top foot)	61	8
Ms21			
Ms20			
Ms19			
Ms18			
Ms17	Limestone, oolitic biosparite, light olive-gray, burrowed, bored?, packed with oysters, bivalves, echinoderm fragments	1	6
	Shale, medium-gray, calcareous, soft	3	0
	Limestone, medium-gray, oolitic, packed with oysters	0	2
Ms16	Shale, medium-gray, soft	5	6



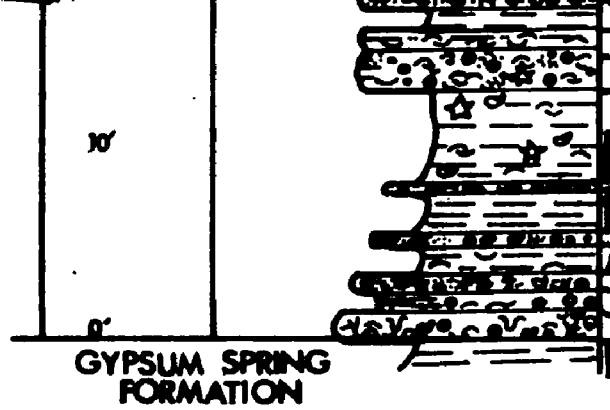
Ms17	Limestone, oolitic biosparite, light olive-gray, burrowed, bored?, packed with oysters, bivalves, echinoderm fragments	1	6
	Shale, medium-gray, calcareous, soft	3	0
	Limestone, medium-gray, oolitic, packed with oysters	0	2
Ms16	Shale, medium-gray, soft	5	6
	Limestone, medium-gray, oolitic	0	3
	Shale, light greenish-brown, soft	2	8
Ms15	Limestone, light-gray, oolitic, burrowed	0	8
	Shale, greenish-brown, soft	1	0
	Limestone, brownish-gray, oolitic, pellets, packed with bivalves	2	3
Ms14	Shale, light brownish-gray, calcareous, soft	5	3
Ms13	Siltstone, medium-gray, bedding flaggy, ripple-marked	0	3
Ms12	Limestone, light olive-gray, oolitic, pellets, bivalves	1	10
Ms11	Shale, medium-gray, soft	1	8
Ms10	Sandstone, light-gray, very fine-grained, calcareous, oolitic, packed with bivalves	1	8
Ms9	Shale, medium-gray, paper-thin	1	1
Ms8	Siltstone, yellowish-gray, calcareous, sandy, bivalves	1	8
Ms7	Limestone, poorly washed sandy oolitic biosparite, pellets, bivalves, echinoderm fragments	1	3
Ms6	Shale, light olive-gray, crinoid columnals, bivalves, gastropods	5	0
Ms5	Sandstone, yellowish-gray, calcareous, packed with bivalves	0	8
Ms4	Shale, brownish-gray, soft	2	0
Ms3	Limestone, oolitic micrite, pellets, gastropods, sandy, light-brown	0	7
Ms2	Claystone, light brownish-gray, calcareous, bivalves	2	10
Ms1	Limestone, poorly-washed sandy oosparite, light brownish-gray, bivalves, gastropods, echinoderms	1	2
	Limestone, light brownish-gray, oolitic, silty, bivalves	1	8
	Limestone, oolitic biopelmicrite, medium-gray, burrbwed, bryozoa, bivalves, gastropods, underlain by red-green claystone of Gypsum Spring Formation	1	6
	Thickness of Stockade Beaver Shale .	101	5
	Total thickness of section .	333	7

LEGEND



GLAUCONITE

CORAL



packed with bivalves	1	8
Ms8 Shale, medium-gray, paper-thin	1	1
Siltstone, yellowish-gray, calcareous, sandy, bivalves	1	8
Limestone, poorly washed sandy oolitic biosparite, pellets, bivalves, echinoderm fragments	1	3
Ms6 Shale, light olive-gray, crinoid columnals, bivalves, gastropods	5	0
Ms5 Sandstone, yellowish-gray, calcareous, packed with bivalves	0	8
Ms4 Shale, brownish-gray, soft	2	0
Limestone, oolitic micrite, pellets, gastropods, sandy, light-brown	0	7
Ms3 Claystone, light brownish-gray, calcareous, bivalves	2	10
Ms2 Limestone, poorly-washed sandy oosparite, light brownish-gray, bivalves, gastropods, echinoderms	1	2
Limestone, light brownish-gray, oolitic, silty, bivalves	1	8
Ms1 Limestone, oolitic biopelmicrite, medium-gray, burrowed, bryozoa, bivalves, gastropods, underlain by red-green claystone of Gypsum Spring Formation	1	6
Thickness of Stockade Beaver Shale	101	5
Total thickness of section	333	7

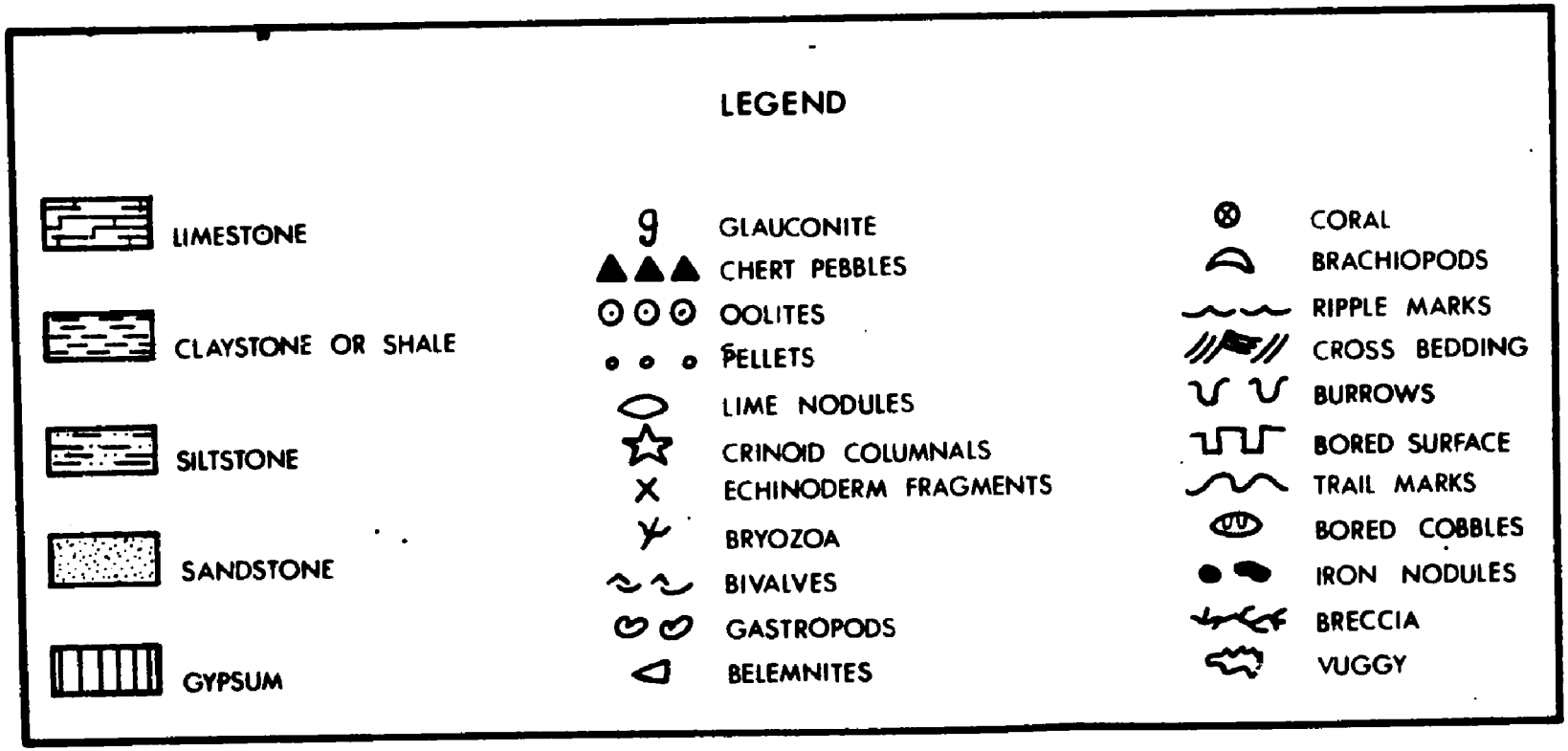
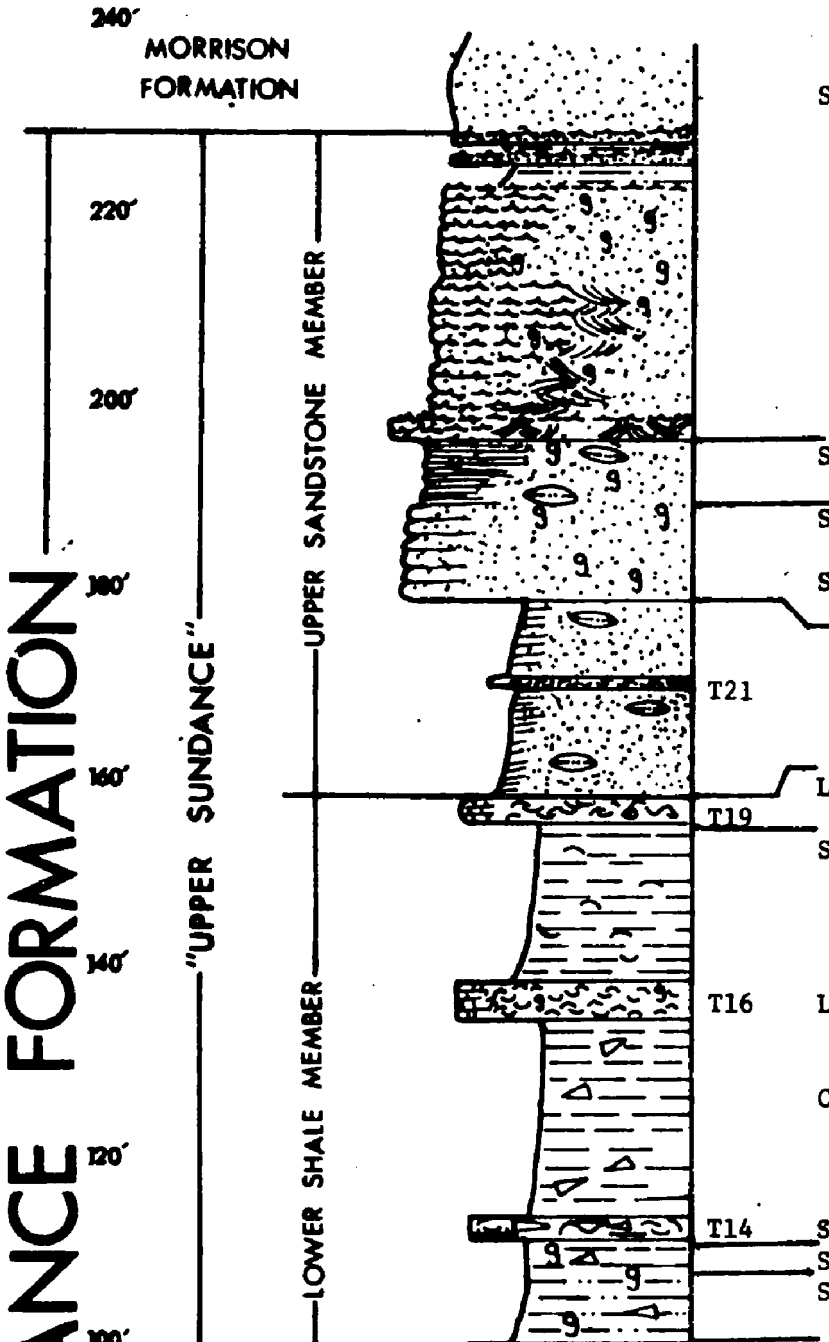
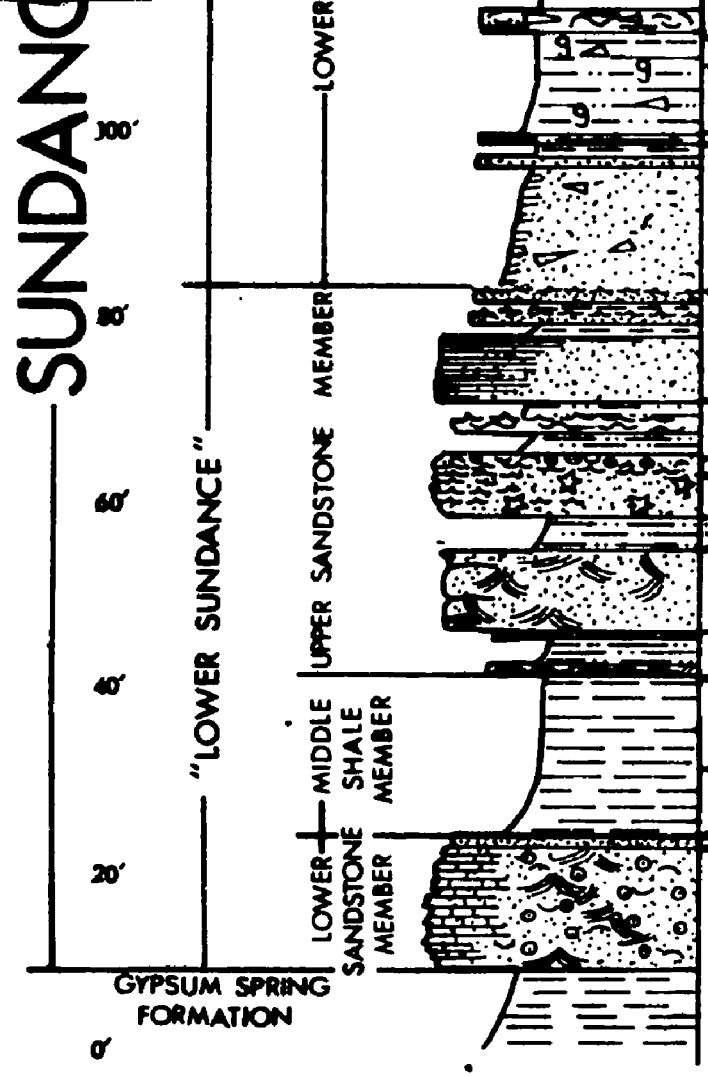


PLATE 16

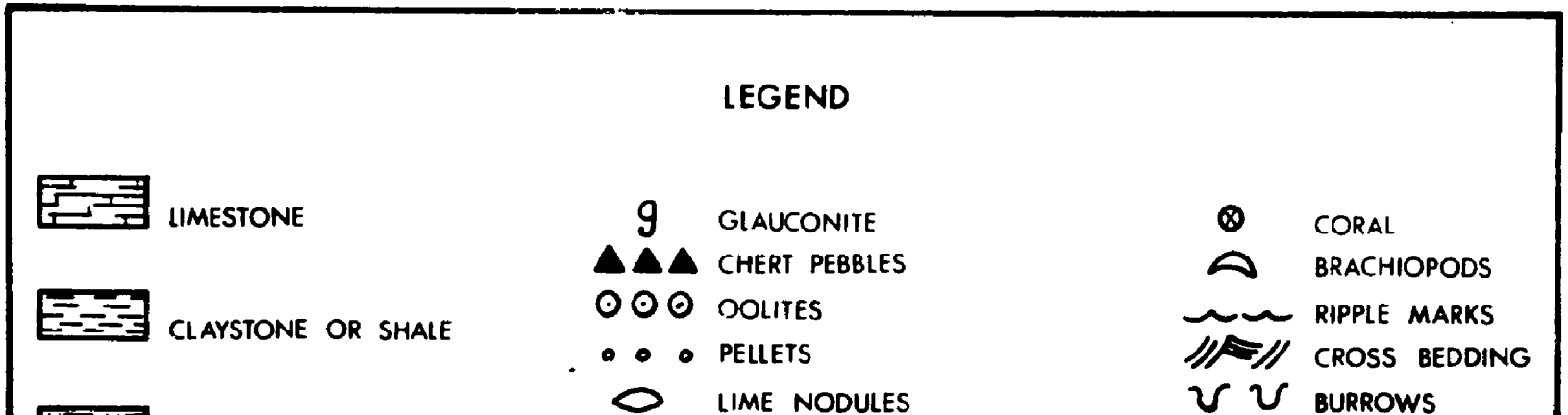
THERMOPOLIS

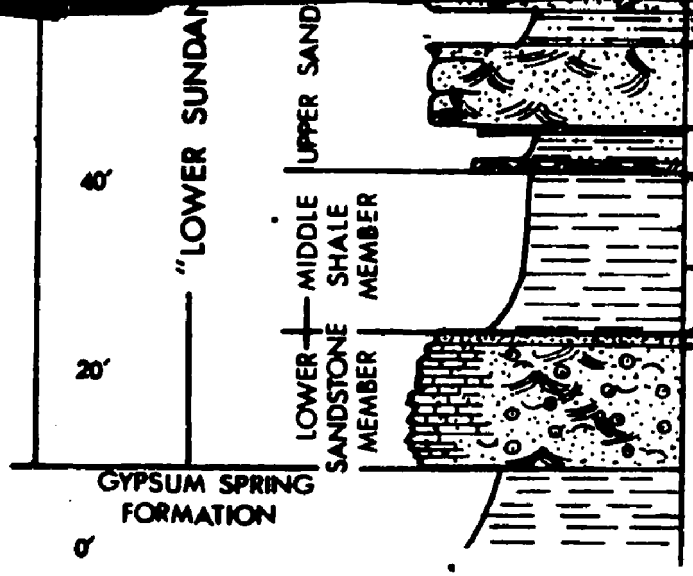


		Ft.	In.
	Sandstone, light greenish-gray, medium-to coarse-grained, calcareous, glauconitic, bedding platy, symmetrically ripple-marked, cross-bedded in lower 14 feet, salt and pepper texture in upper 14 feet, interbeds of siltstone at top, overlain by white massive sandstone of Morrison	30	0
	Sandstone, brownish-gray, very fine-grained, calcareous, glauconitic, bedding platy	8	0
	Sandstone, grayish-white, very fine-grained, calcareous, glauconitic, harder than overlying sandstone	10	0
	Sandstone, brownish-gray, fine-grained, soft, silty, middle of unit is resistant and contains bivalves	20	4
	Thickness of Upper Sandstone .	68	4
T21			
	Limestone, biosparite, yellowish-gray, packed with bivalves ..	2	3
T19			
	Shale, dark-gray, calcareous, oyster shells on slope	18	0
T16	Limestone, very pale-orange, coarsely-crystalline, glauconitic, medium-bedded, packed with bivalves	2	8
	Claystone, greenish-gray, calcareous, belemnites	22	0
T14	Siltstone, olive-gray, calcareous, packed with bivalves	1	0
	Shale, greenish-gray, calcareous	3	0
	Siltstone, greenish-gray, glauconitic, belemnites	10	0



Siltstone, olive-gray, calcareous, packed with bivalves	1	0
Shale, greenish-gray, calcareous	3	0
Siltstone, greenish-gray, glauconitic, belemnites	10	0
Limestone, medium-gray, crystalline	0	6
Sandstone, white, very fine-grained, interbeds of gray shale .	1	8
Sandstone, light-tan, very fine-grained, soft, belemnites	12	0
Thickness of lower shale .	73	1
Sandstone, white, fine-grained, calcareous, thin-bedded, symmetrically ripple-marked and interbedded with gray shale in top 5 feet	11	6
Siltstone, greenish-gray, interbeds of ripple and trail-marked sandstone	8	0
Limestone, pale yellowish-brown, oolitic, bivalves	0	10
Sandstone, white, fine-grained, calcareous, thin-bedded, ripple-marked crinoid columnals	4	6
Siltstone, greenish-gray, soft	3	6
Sandstone, white, hematite specked, fine-grained, calcareous, cross-bedded	10	0
Siltstone, medium-gray, interbeds of cross-bedded sandstone ..	4	0
Thickness of Upper Sandstone .	40	10
Claystone, greenish-gray, calcareous	9	0
Shale, medium-gray, calcareous	10	0
Thickness of Middle Shale .	19	0
Sandstone, yellow, medium-grained	0	10
Limestone, poorly washed sandy oosparite, grayish-brown, thin-bedded, oyster shell fragments, thin beds are cross-bedded, white bands of quartz sand alternate with bands of oolites, underlain by red shale of Gypsum Spring Formation	14	0
Thickness of Lower Sandstone .	14	10
Total thickness of section .	215	3





Sandstone, white, fine-grained, calcareous, thin-bedded, ripple-marked crinoid columnals	4	6
Siltstone, greenish-gray, soft	3	6
Sandstone, white, hematite specked, fine-grained, calcareous, cross-bedded	10	0
Siltstone, medium-gray, interbeds of cross-bedded sandstone	4	0
Thickness of Upper Sandstone	40	10
Claystone, greenish-gray, calcareous	9	0
Shale, medium-gray, calcareous	10	0
Thickness of Middle Shale	19	0
Sandstone, yellow, medium-grained	0	10
Limestone, poorly washed sandy oosparite, grayish-brown, thin-bedded, oyster shell fragments, thin beds are cross-bedded, white bands of quartz sand alternate with bands of oolites, underlain by red shale of Gypsum Spring Formation	14	0
Thickness of Lower Sandstone	14	10
Total thickness of section	215	3

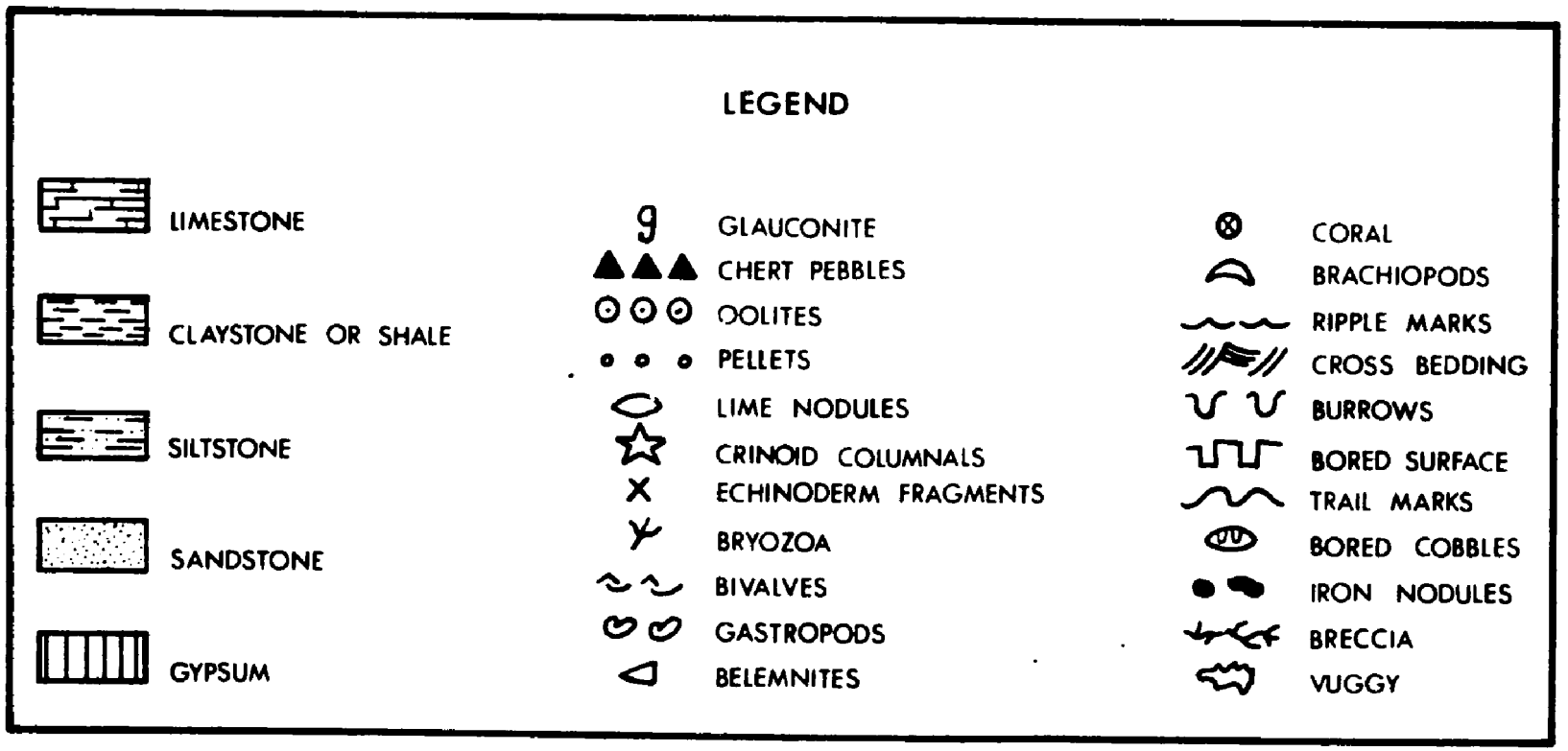
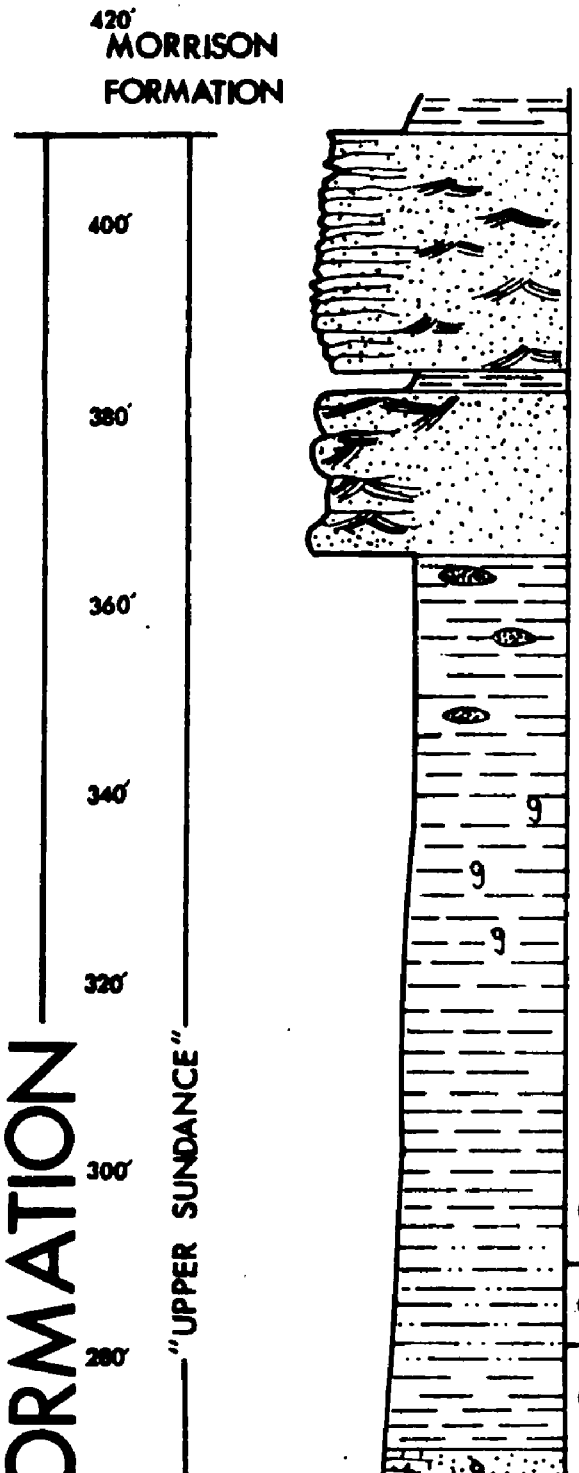
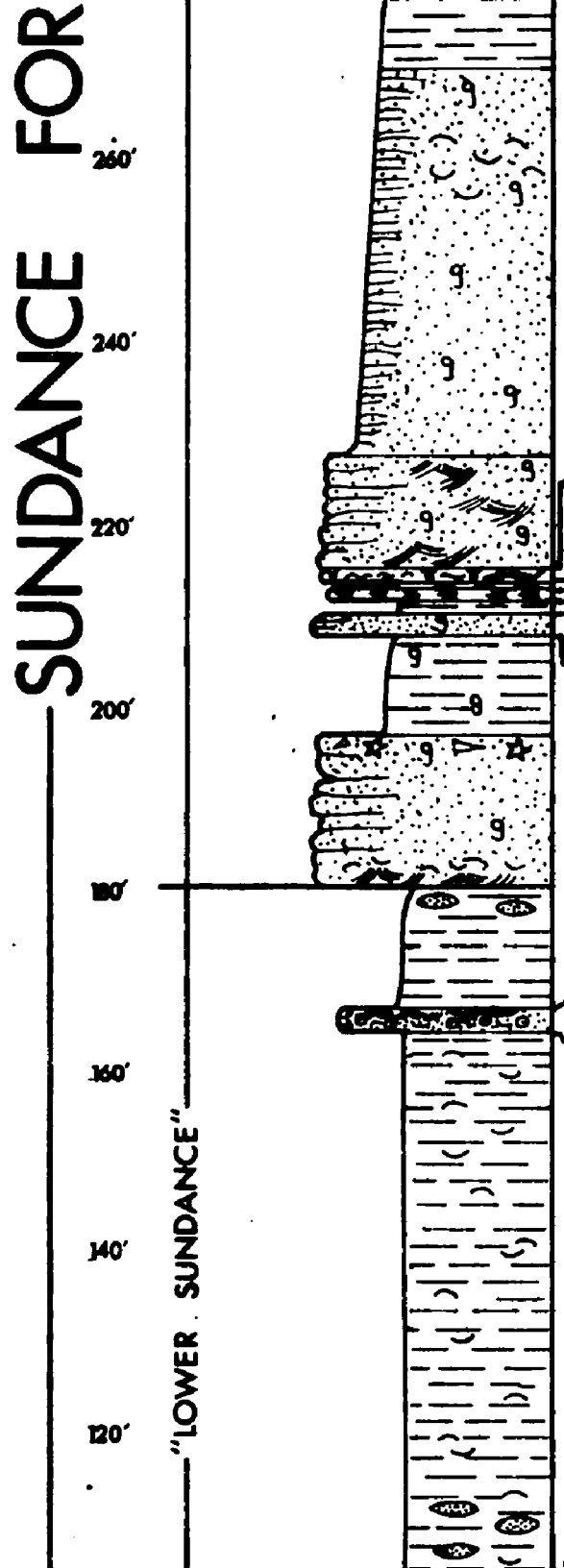


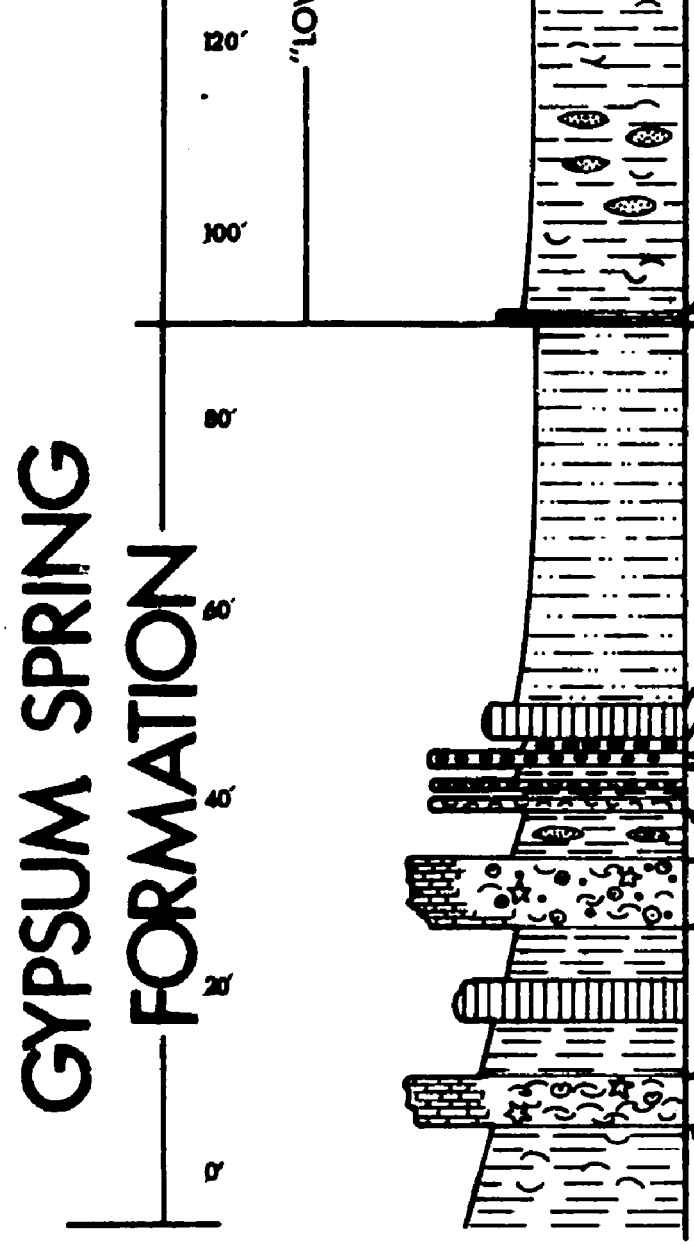
PLATE 17



		Ft.	In.
	Sandstone, white, medium-grained, thin-bedded, cross-bedded overlain by varicolored shale of Morrison	26	0
	Shale, dark-gray, calcareous, soft	1	0
	Sandstone, light yellowish-tan, medium-to-coarse-grained, calcareous, thick-bedded, cross-bedded	29	0
C33	Shale, olive-gray, calcareous, soft, sandy in upper part, glauconitic in middle	57	0
C28	Shale, alternating beds of gray and maroon	32	0
C27	Siltstone, calcareous, alternating beds of gray and maroon	9	0
	Shale, olive-gray, calcareous, soft	11	0

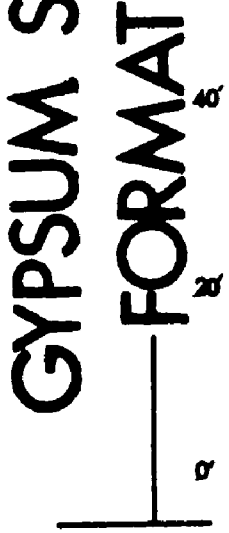


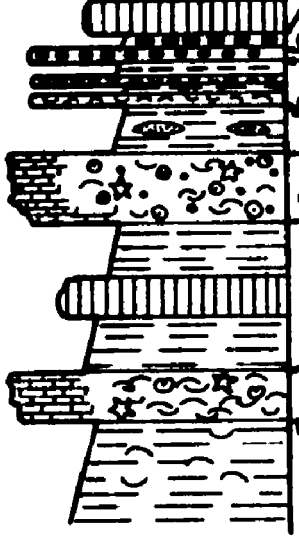
Sandstone, greenish-gray, calcareous, thin-bedded, glauconitic, soft, bivalves	50	2
Sandstone, medium-gray, calcareous, glauconitic, medium-grained, medium-bedded, cross-bedded	13	0
Sandstone, pale yellowish-brown, medium-grained, calcareous, glauconitic, cross-bedded, burrowed, bivalves	1	0
Shale, medium-gray	0	8
Limestone, medium-gray, sandy, crinoid columnals	1	3
Shale, medium-gray	2	0
Sandstone, greenish-gray, calcareous, glauconitic, medium-grained, thin-bedded	4	0
Shale, grayish-green, calcareous, glauconitic	11	0
Sandstone, pale yellowish-brown, salt and pepper texture, medium-grained, glauconitic, calcareous; cross-bedded at base, bivalves 4 feet above base, belemnite and crinoid columnals at top	17	0
Thickness of "Upper Sundance"	253	3
Shale, dark greenish-gray, sandy at top	13	6
Sandstone, white, very fine-grained, calcareous, oolitic, cross-bedded, bivalves	2	3
Shale, light olive-gray, calcareous, sandy at bottom, bivalves	72	8



Limestone, light-gray, lithographic	0	8
Thickness of "Lower Sundance"	88	5
Siltstone, reddish-maroon, soft	42	0
Gypsum, white, soft	4	0
Siltstone, light brownish-gray, calcareous, bedding-platy, corals	3	0
Limestone, medium-gray, oolitic	0	6
Limestone, medium-gray, packed with bivalves, interbeds of grayish-brown shale	7	10
Shale, medium-gray, sandy	3	6
Limestone, poorly-washed packed biosparite, light brownish-gray, sandy, bedding platy, bivalves, oolites, pellets, crinoid columnals	7	0
Shale, greenish-gray, calcareous	6	0
Gypsum, white, soft	4	0
Shale, dark-gray, calcareous, soft	7	0
Limestone, poorly-washed packed biosparite, light brownish-gray, bedding platy, bivalves, gastropods, crinoid columnals	5	0
Shale, light-gray calcareous, soft, bivalves, underlain by red shale in the lower part of the Gypsum Spring Formation.	7	0
Thickness of Gypsum Spring Formation	100	10
Total thickness of section	442	6

LEGEND





C6	Limestone, medium-gray, packed with bivalves, interbeds of grayish-brown shale	7 10
C5	Shale, medium-gray, sandy	3 6
C4	Limestone, poorly-washed packed biosparite, light brownish-gray, sandy, bedding platy, bivalves, oolites, pellets, crinoid columnals	7 0
	Shale, greenish-gray, calcareous	6 0
	Gypsum, white, soft	4 0
C3	Shale, dark-gray, calcareous, soft	7 0
C2	Limestone, poorly-washed packed biosparite, light brownish-gray, bedding platy, bivalves, gastropods, crinoid columnals	5 0
C1	Shale, light-gray calcareous, soft, bivalves, underlain by red shale in the lower part of the Gypsum Spring Formation.	7 0
	Thickness of Gypsum Spring Formation .	100 10
	Total thickness of section .	442 6

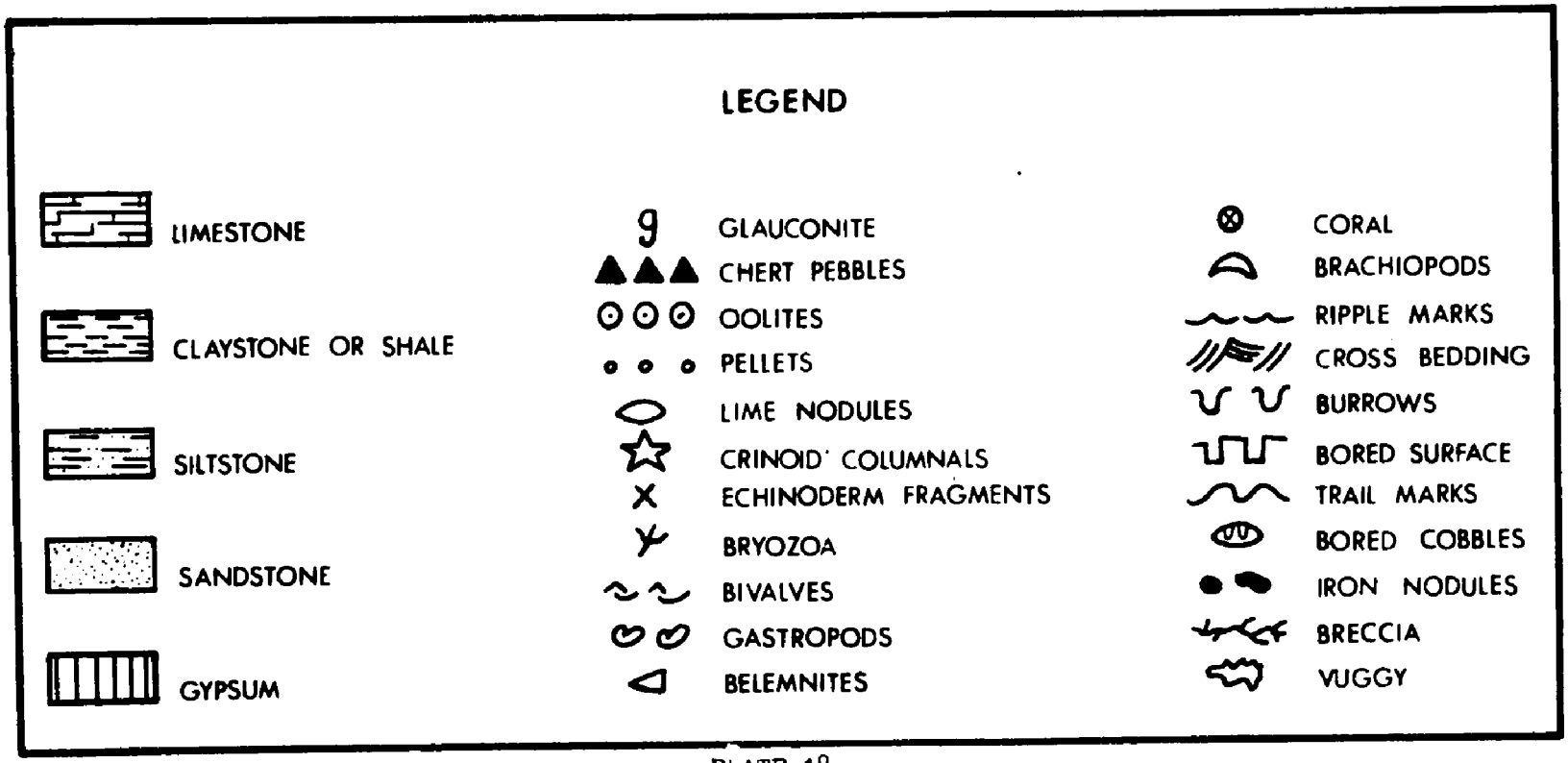
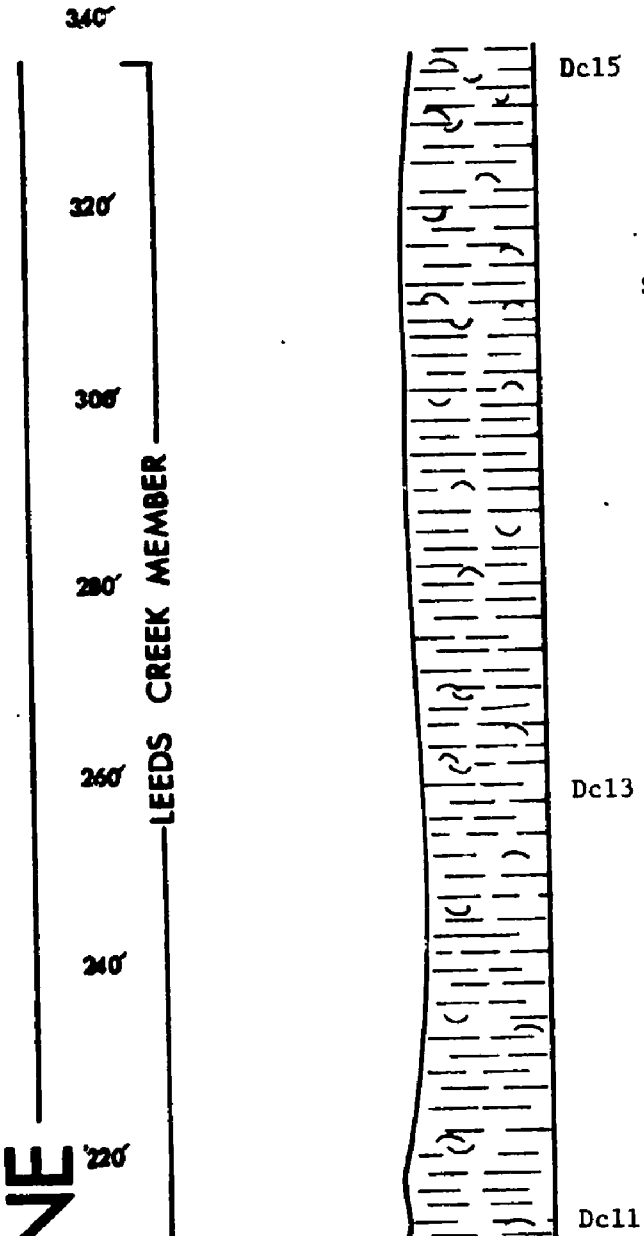


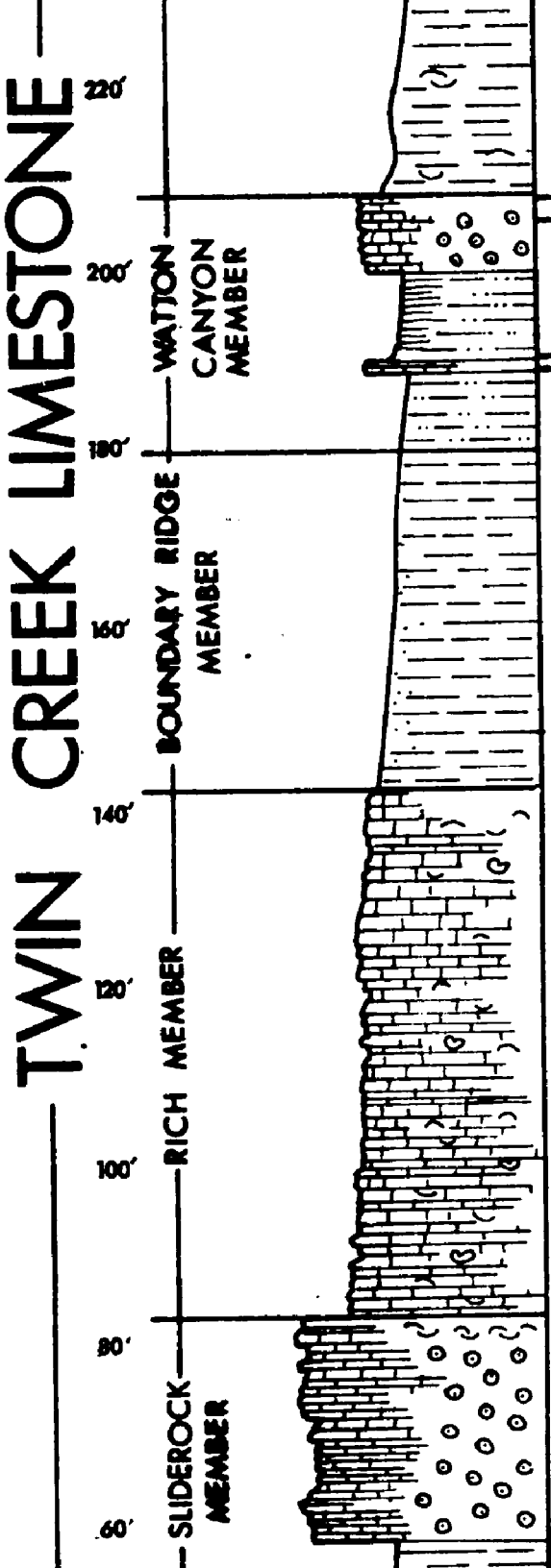
PLATE 18

DITCH CREEK

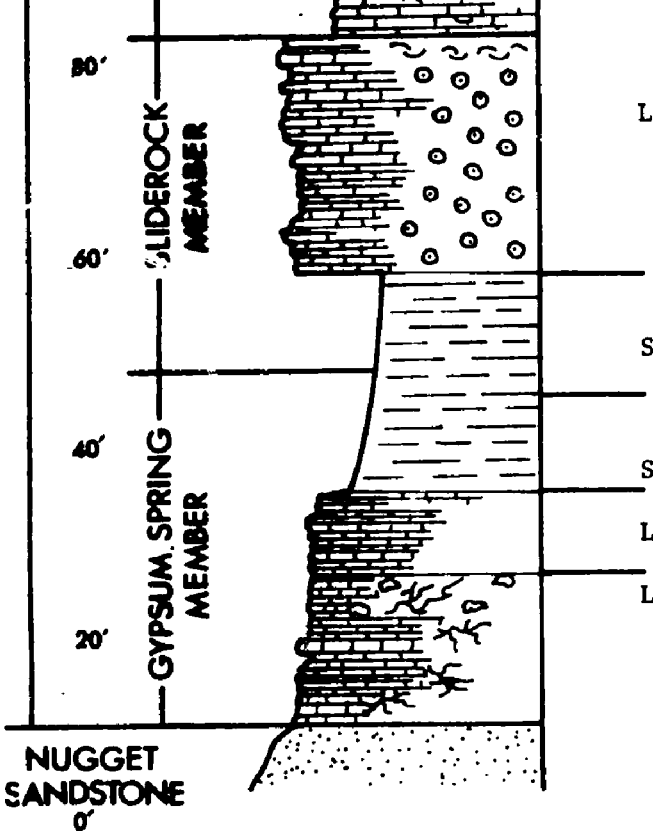
PLATE 19



Shale, light-gray, very calcareous, hard, bivalves	130	0
Thickness of Leeds Creek Member .	130	0



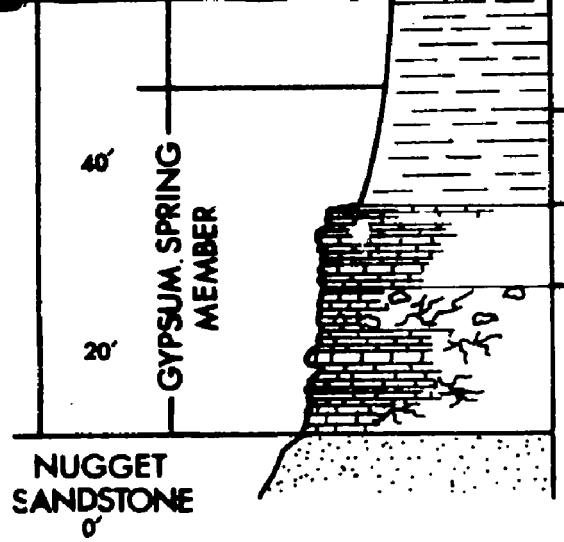
Limestone, dark-gray, hard	1	0
Limestone, medium-gray, medium-bedded, oolitic	8	0
Siltstone, medium-gray, calcareous, hard, bedding platy	10	0
Limestone, dark-gray, lithographic	2	0
Siltstone, brownish-gray, calcareous, thin-bedded	10	0
Thickness of Watton Canyon	31	0
Shale, reddish-brown, calcareous, soft	40	0
Thickness of Boundary Ridge Member	40	0
Limestone, sparse biomicrite, light olive-gray, hard, bedding platy, bivalves and gastropods	59	0
Thickness of Rich Member	59	0
Limestone, oosparite, medium-gray, medium-to-thin-bedded, oyster fragments at top	25	0



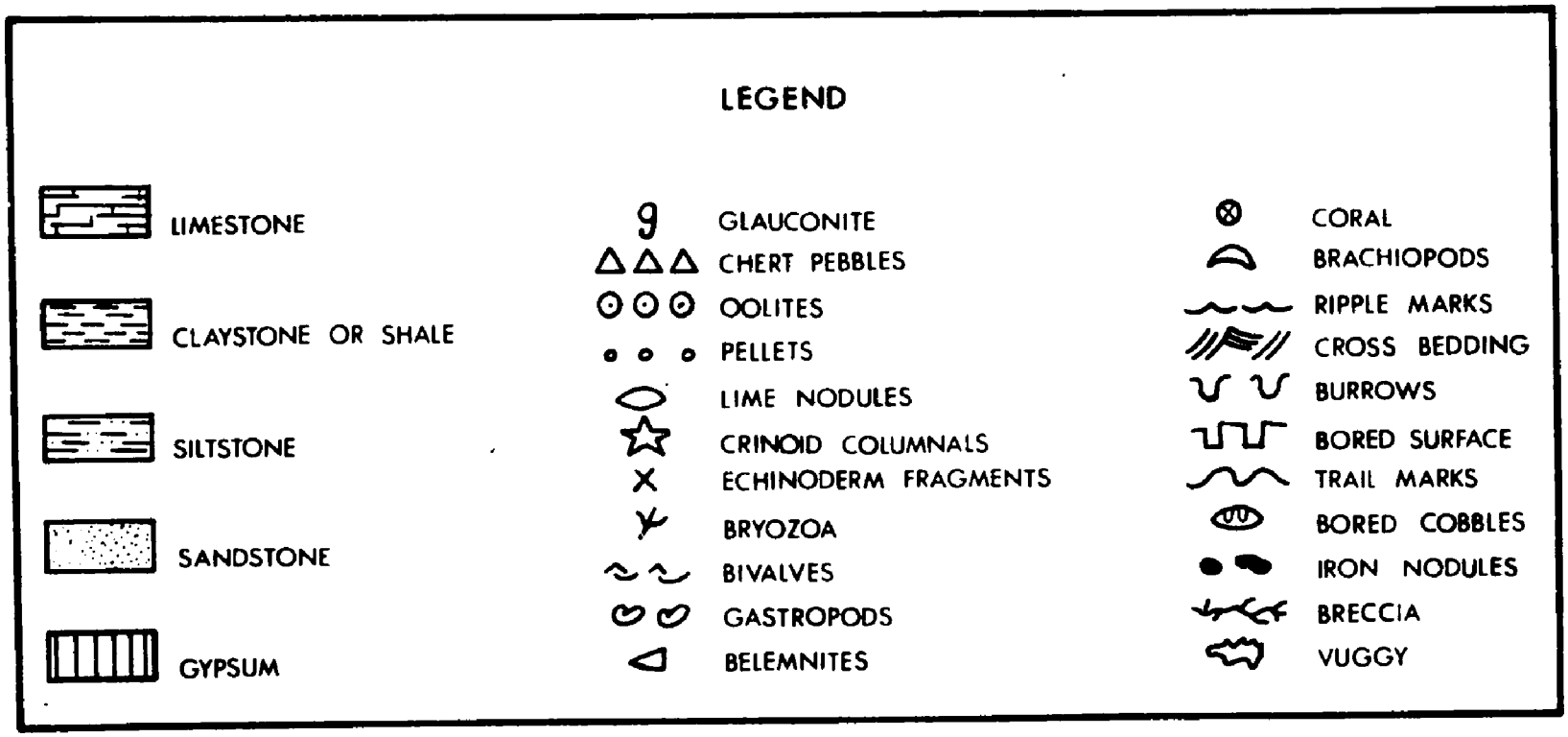
Limestone, oosparite, medium-gray, medium-to-thin-bedded, oyster fragments at top	25	0
Shale, brownish-gray, calcareous, silty	12	0
Thickness of Sliderock Member .	37	0
Shale, red, soft	11	0
Limestone, pinkish-gray, crystalline, bedding platy	7	0
Limestone, light-pink, breciated, juggy near top, underlain by salmon-red sandstone of Nugget	16	0
Thickness of Gypsum Spring Member .	34	0
Total thickness of section .	331+	0

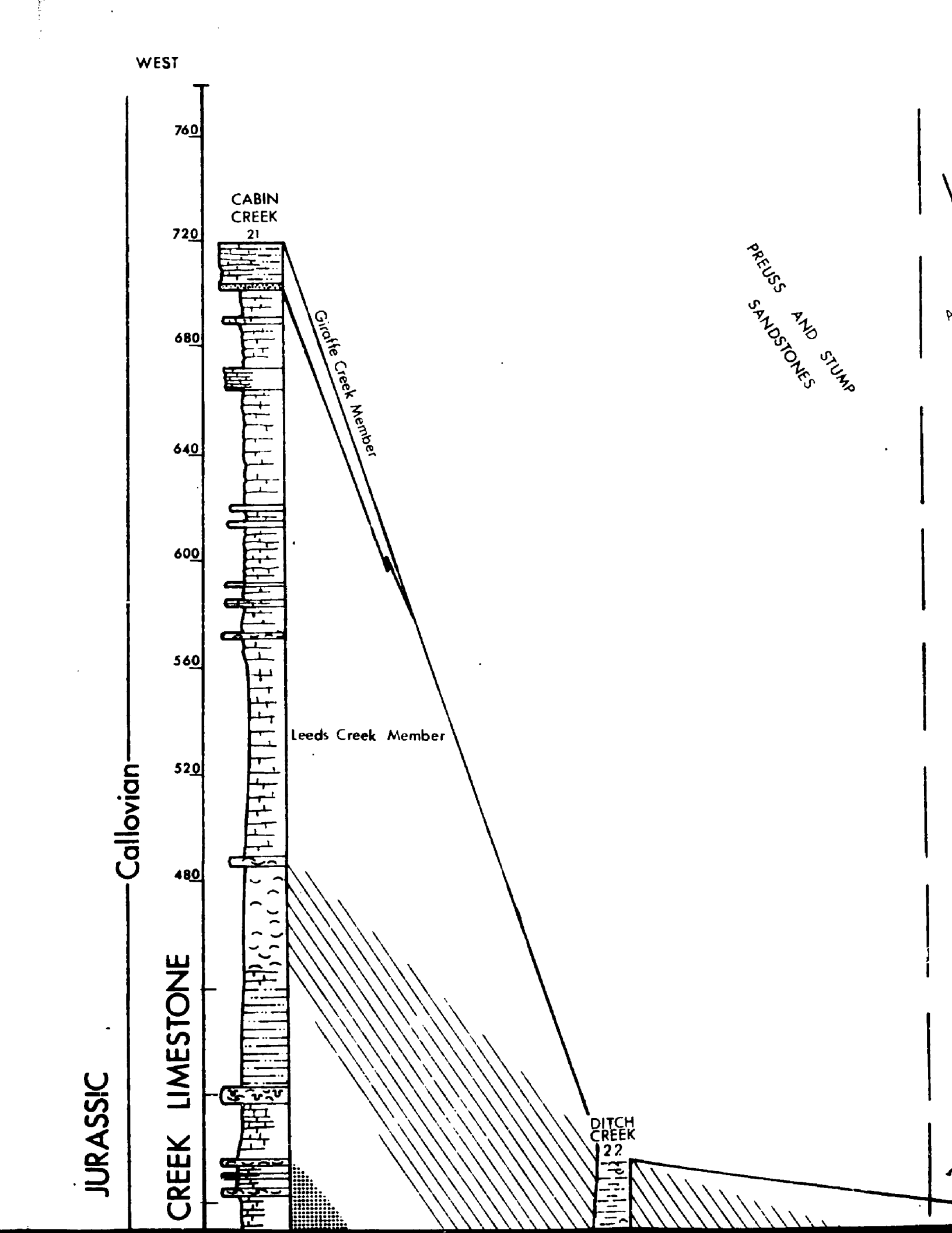
LEGEND

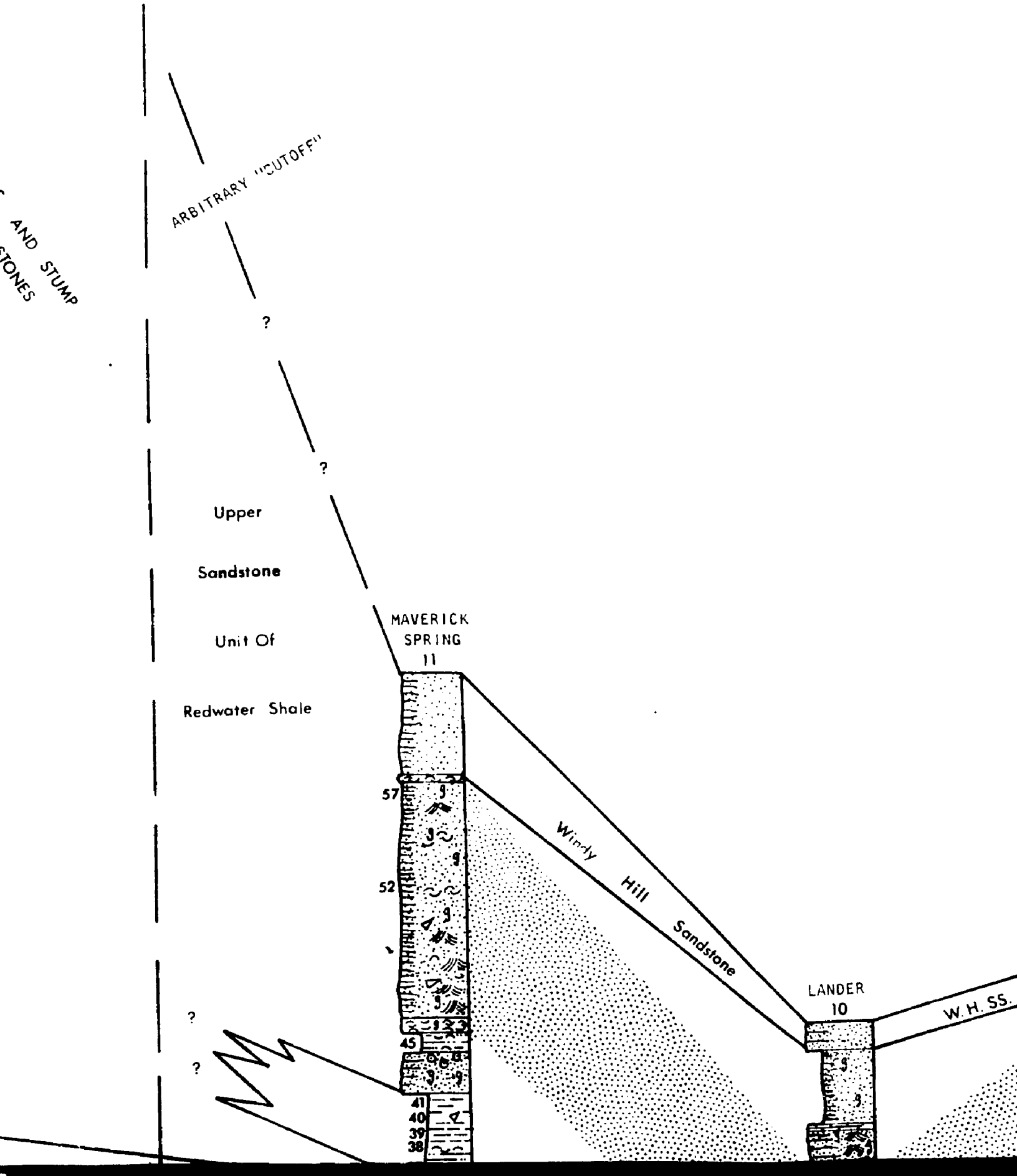
- LIMESTONE
- CLAYSTONE OR SHALE
- SILTSTONE
- SANDSTONE
- GLAUCONITE
- CHERT PEBBLES
- OOLITES
- PELLETS
- LIME NODULES
- CRINOID COLUMNALS
- ECHINODERM FRAGMENTS
- BRYOZOA
- BIVALVES
- CORAL
- BRACHIOPODS
- RIPPLE MARKS
- CROSS BEDDING
- BURROWS
- BORED SURFACE
- TRAIL MARKS
- BORED COBBLES
- IRON NODULES

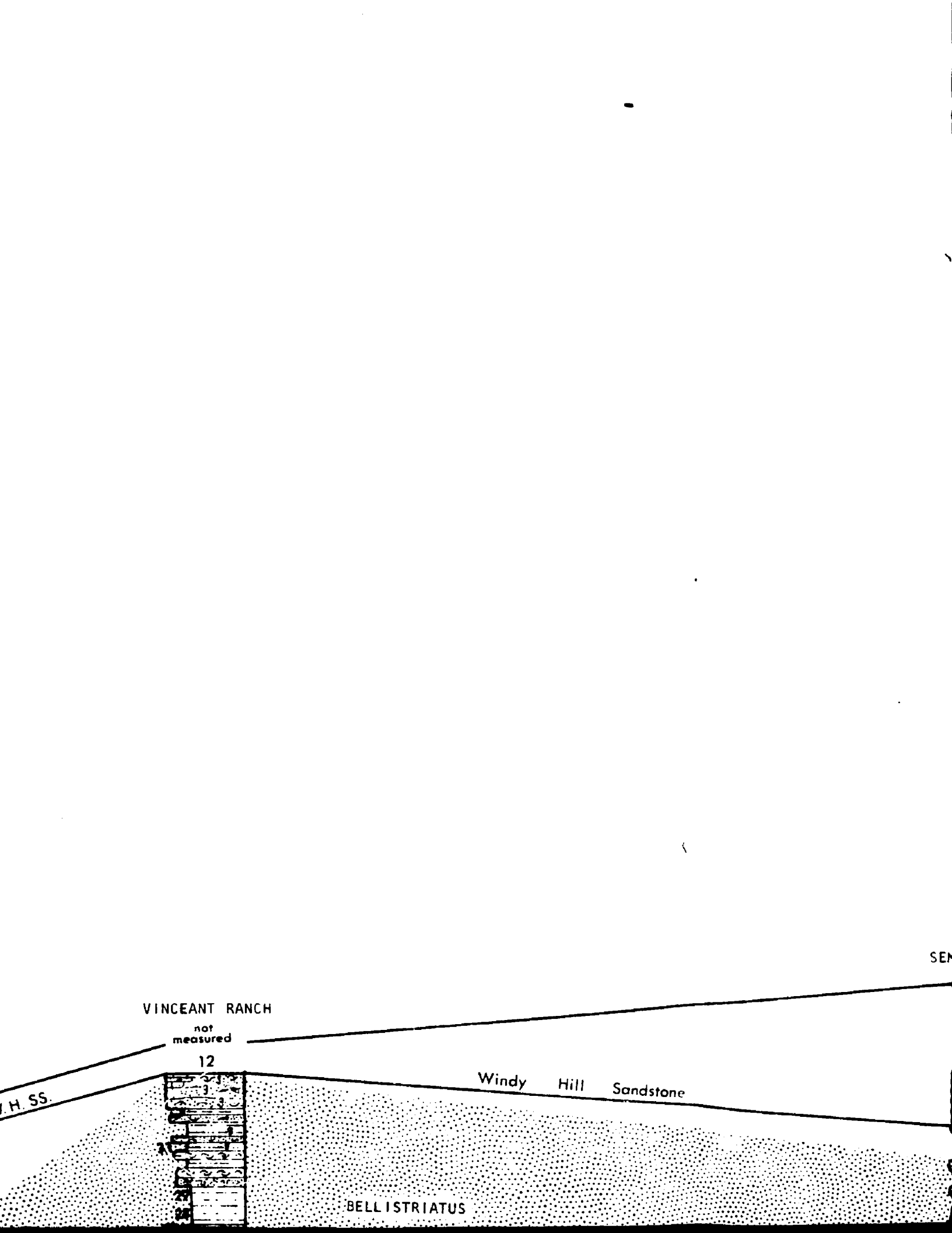


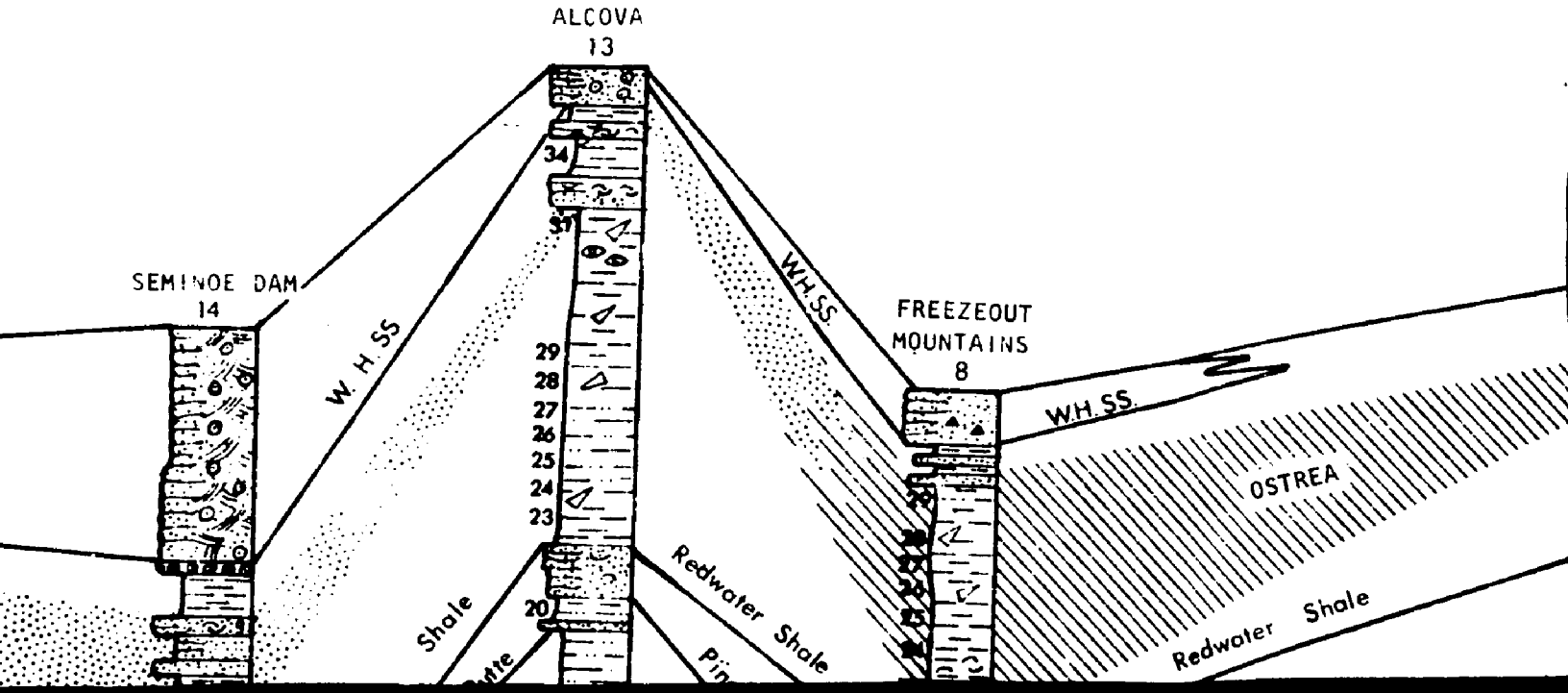
Shale, brownish-gray, calcareous, silty	12	0
Thickness of Sliderock Member .	37	0
Shale, red, soft	11	0
Limestone, pinkish-gray, crystalline, bedding platy	7	0
Limestone, light-pink, breciated, juggy near top, underlain by salmon-red sandstone of Nugget	16	0
Thickness of Gypsum Spring Member .	34	0
Total thickness of section .	331+	0

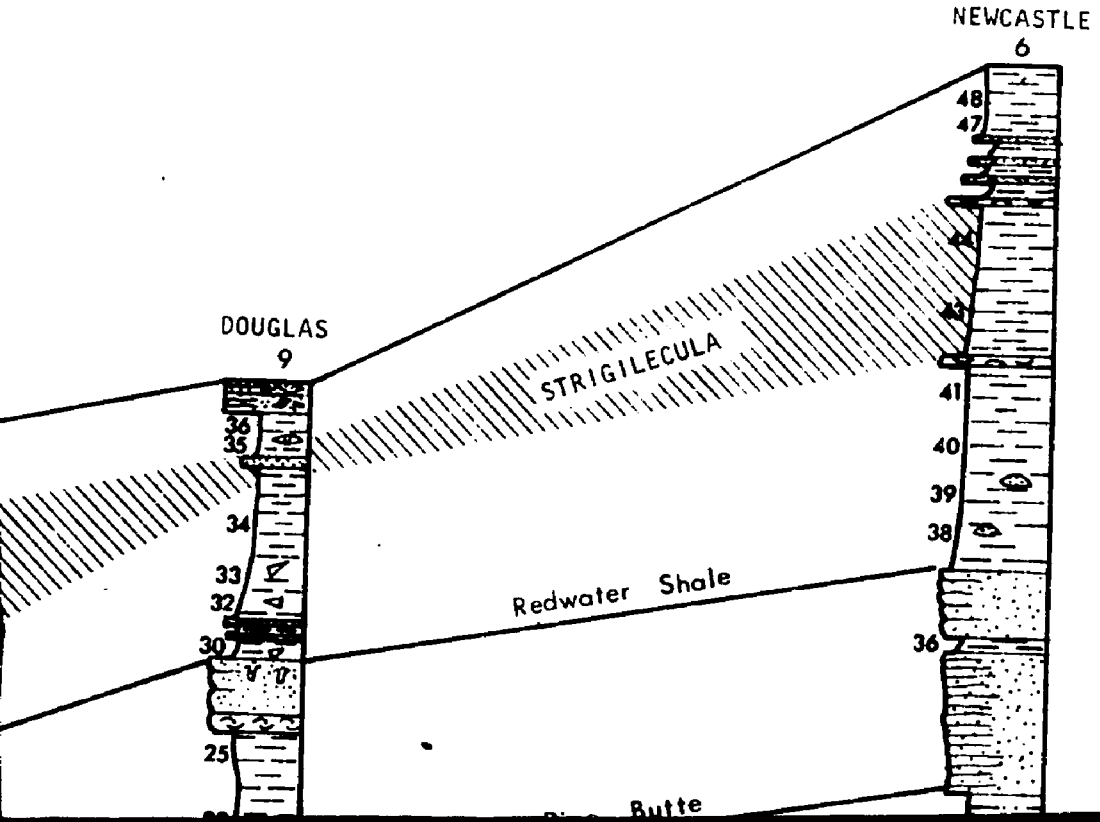



WEST
760
720
680
640
600
560
520
480
CABIN CREEK
21
Giraffe Creek Member
Leeds Creek Member
PREUSS AND STUMP SANDSTONES
DITCH CREEK
22
JURASSIC
Callovian
CREEK LIMESTONE

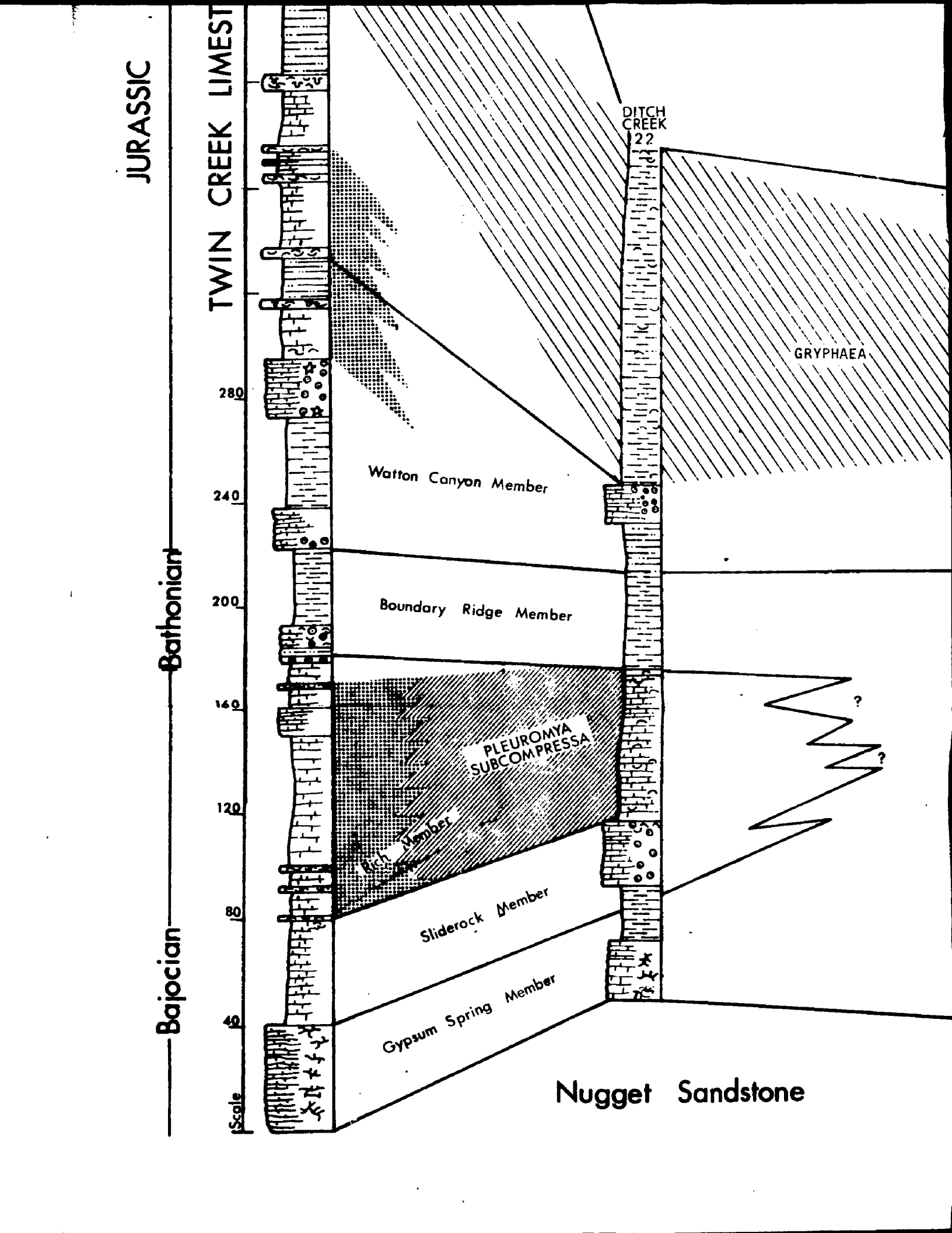

AND STUMP
STONES
ARBITRARY "CUTOFF"
?
?
Upper
Sandstone
Unit Of
Redwater Shale
MAVERICK
SPRING
11
57
52
45
41
40
39
38
Windy Hill Sandstone
LANDER
10
W.H. SS.
?
?

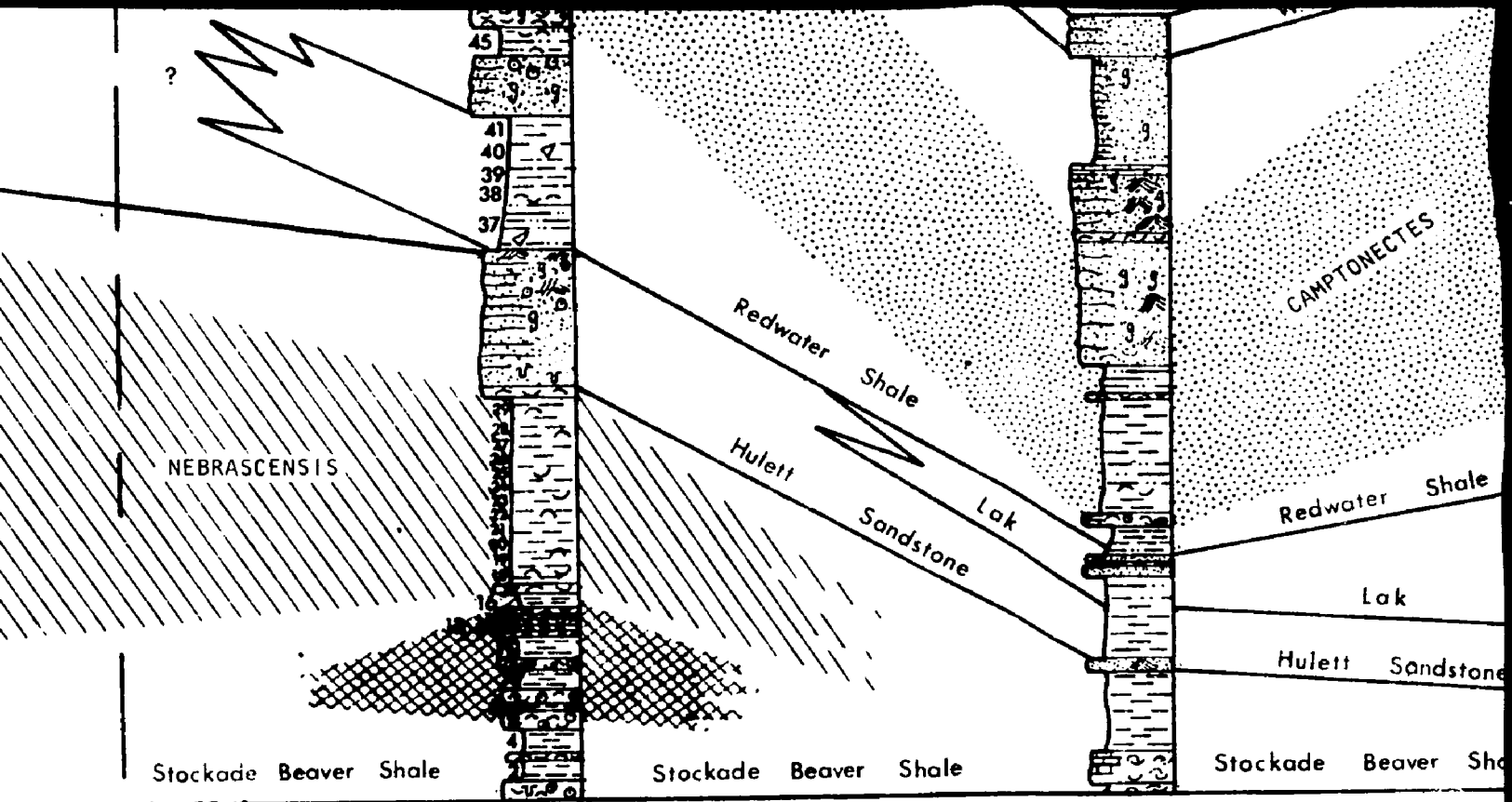

SEN
VINCEANT RANCH
not measured
12
Windy Hill Sandstone
BELLISTRIATUS


ALCOVA
13
SEMINOE DAM
14
FREEZEOUT
MOUNTAINS
8
W.H.SS.
W.H.SS.
W.H.SS.
34
31
29
28
27
26
25
24
23
20
OSTREA
Redwater Shale
Redwater Shale
Shale


NEWCASTLE
6
DOUGLAS
9
STRIGILECULA
Redwater Shale
48
47
41
40
39
38
36
34
33
32
30
25

EAST


JURASSIC
Bathonian
Bajocian
TWIN CREEK LIMEST
280
240
200
160
120
80
40
Scale
DITCH CREEK 22
GRYPHAEA
Watton Canyon Member
Boundary Ridge Member
PLEUROMYA SUBCOMPRESSA
Rich Member
Sliderock Member
Gypsum Spring Member
?
?
Nugget Sandstone



Gypsum Spring Formation

Gypsum Spring Formation

LIMESTONE

CLAYSTONE OR SHALE

SILTSTONE

SANDSTONE

GYPSUM

GLAUCONITE

CHERT PEBBLES

OOLITES

CRINOID COLUMNA

BIVALVES

BELEMNITES

CROSS BEDDING

BURROWS

BORED SURFACE

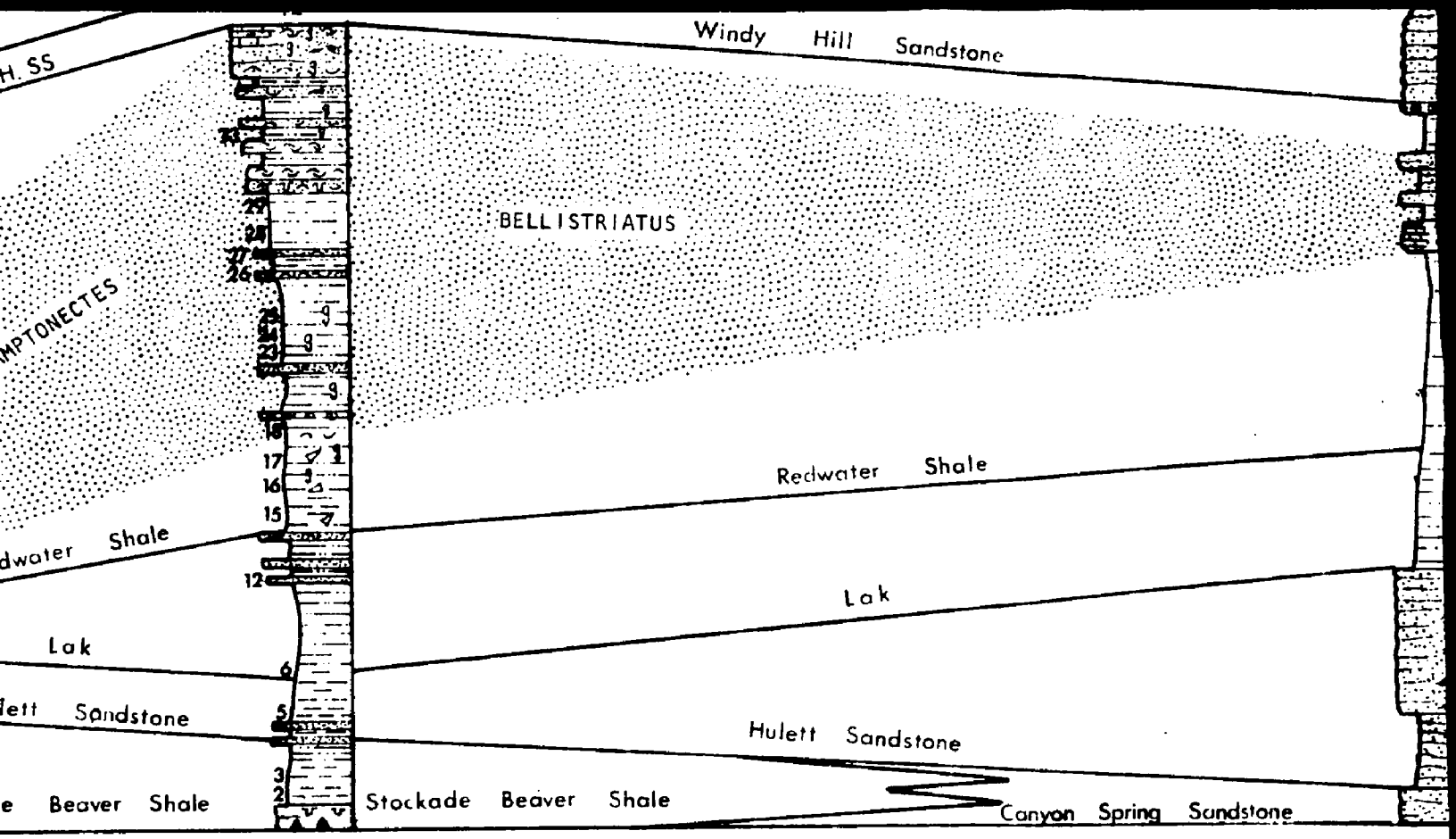
BORED COBBLES

IRON NODULES

BRECCIA

Verti
Horizont

numbers to the left of sections 6, 8



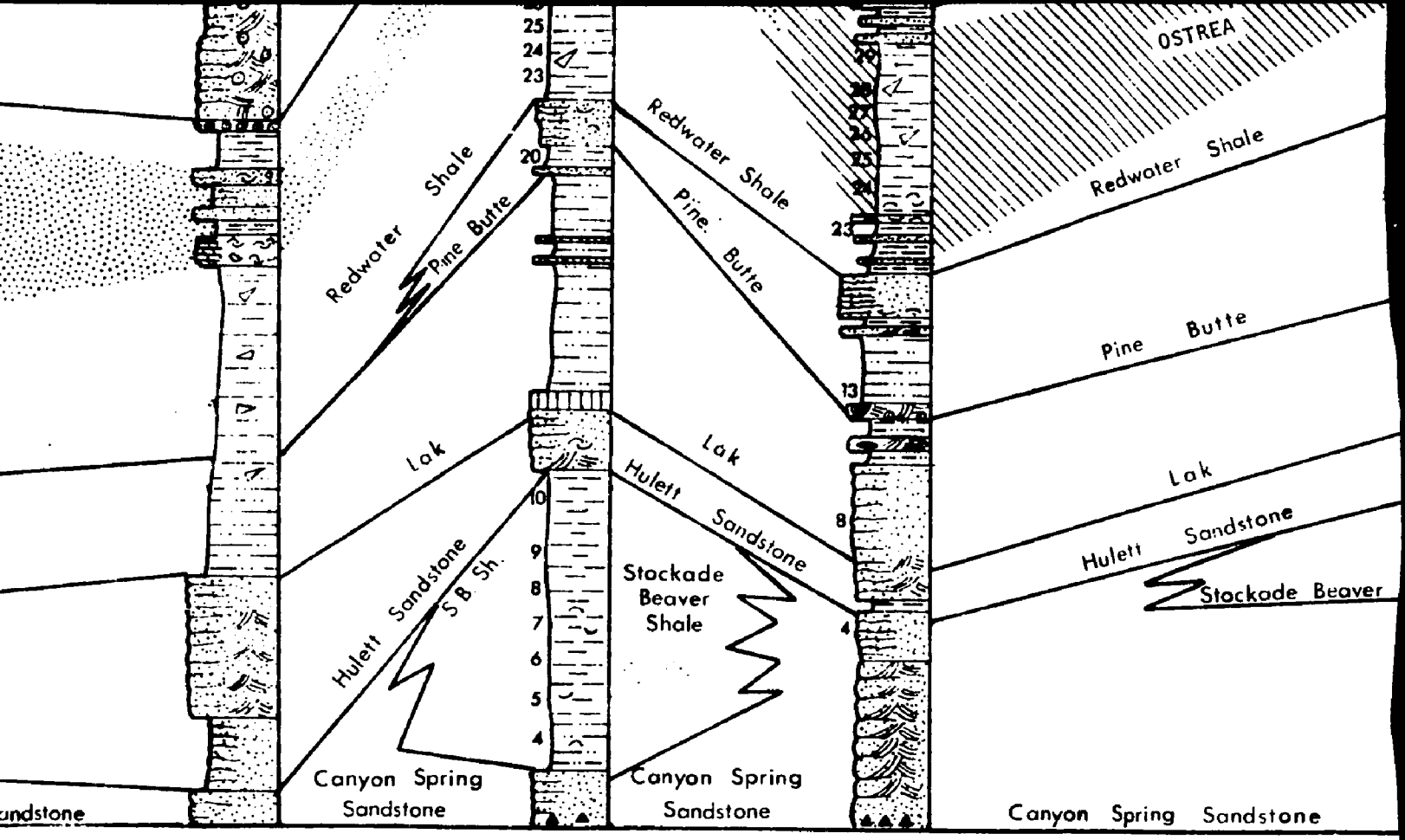
LEGEND

AUCONITE
ERT PEBBLES
OLITES
INOID COLUMNALS
VALVES
LEMNITES
OSS BEDDING
RROWS
ORED SURFACE
ORED COBBLES
ON NODULES
ECCIA

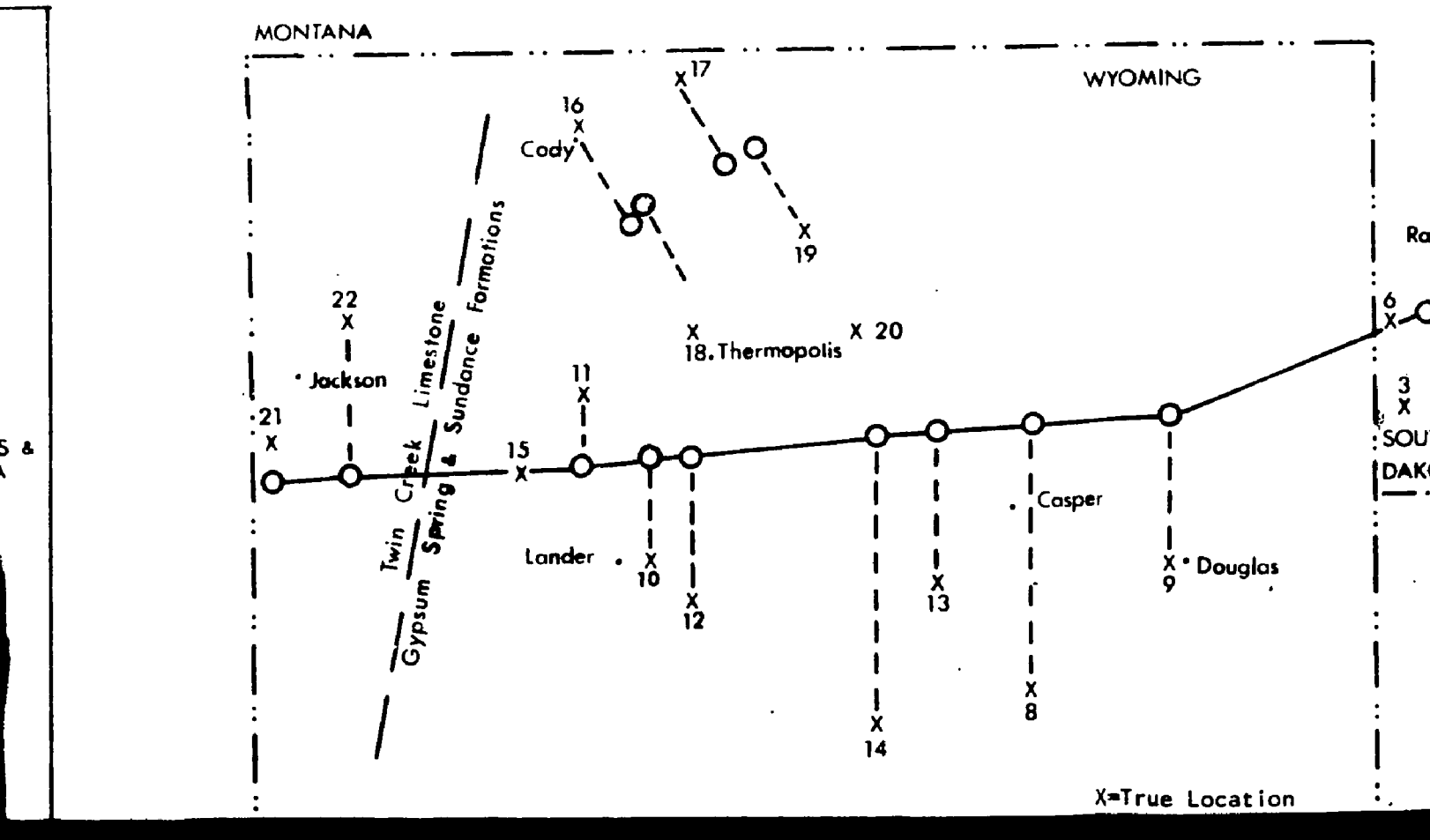
BIVALVE BIOFACIES

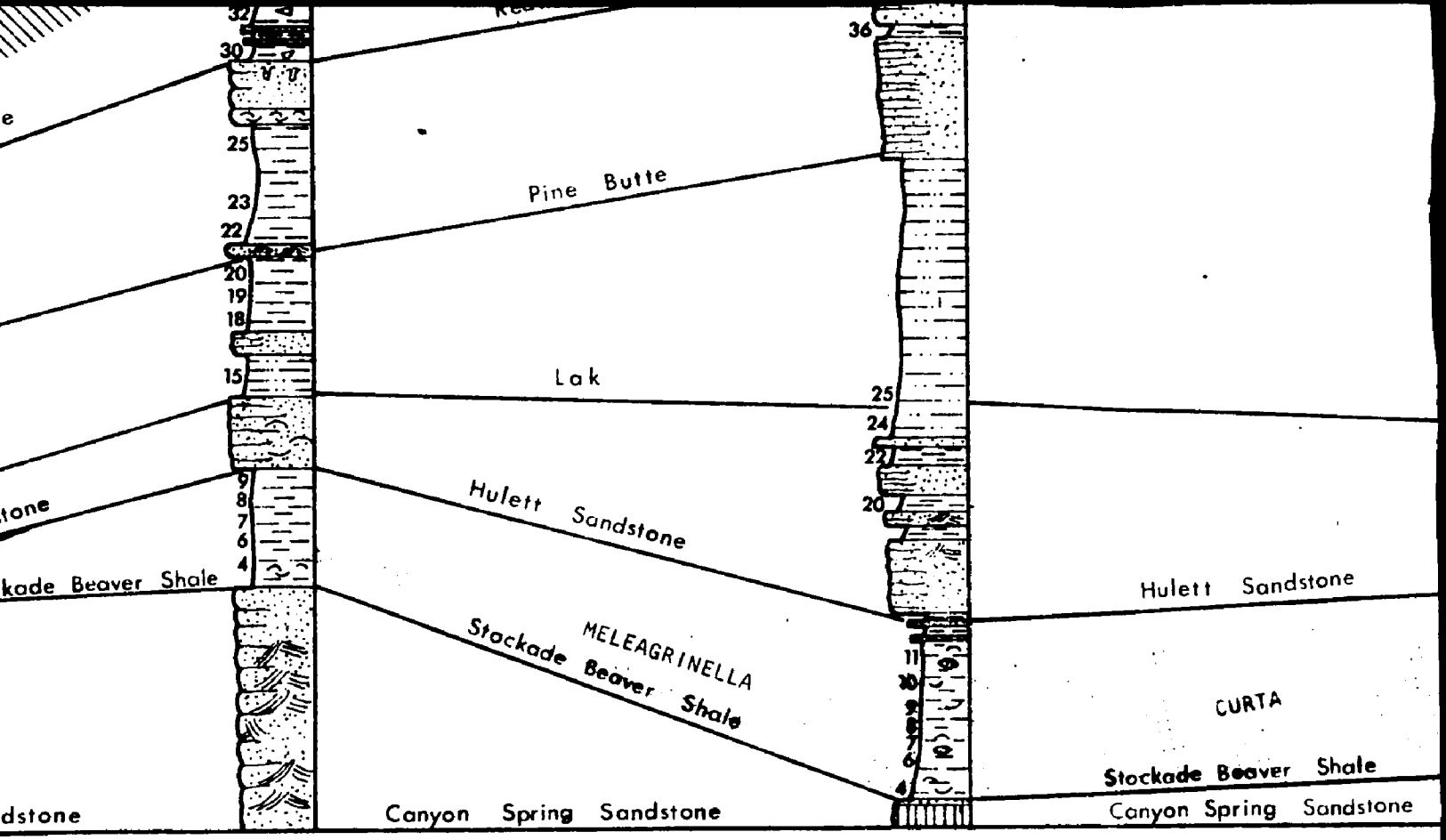
- CAMPTONECTES BELLESTRIATUS
- PLEUROMYA SUBCOMPRESSA
- TRIGONIA AMERICANA
- MELEAGRINELLA CURTA
- GRYPHAEA NEBRASCENSIS
- PRONOELLA CINNABARENSIS & PLEUROMYA SUBCOMRESSA
- CAMPTONECTES STYGIUS
- OSTREA STRIGILECULA

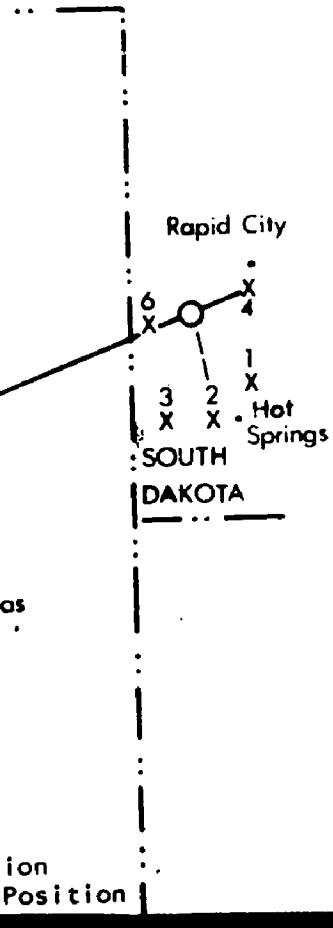
Vertical Scale 1" = 40'
Horizontal distance not to scale
sections 6, 8, 9, 11, 12, 13, 16, and 20 indicate microfossil samples.



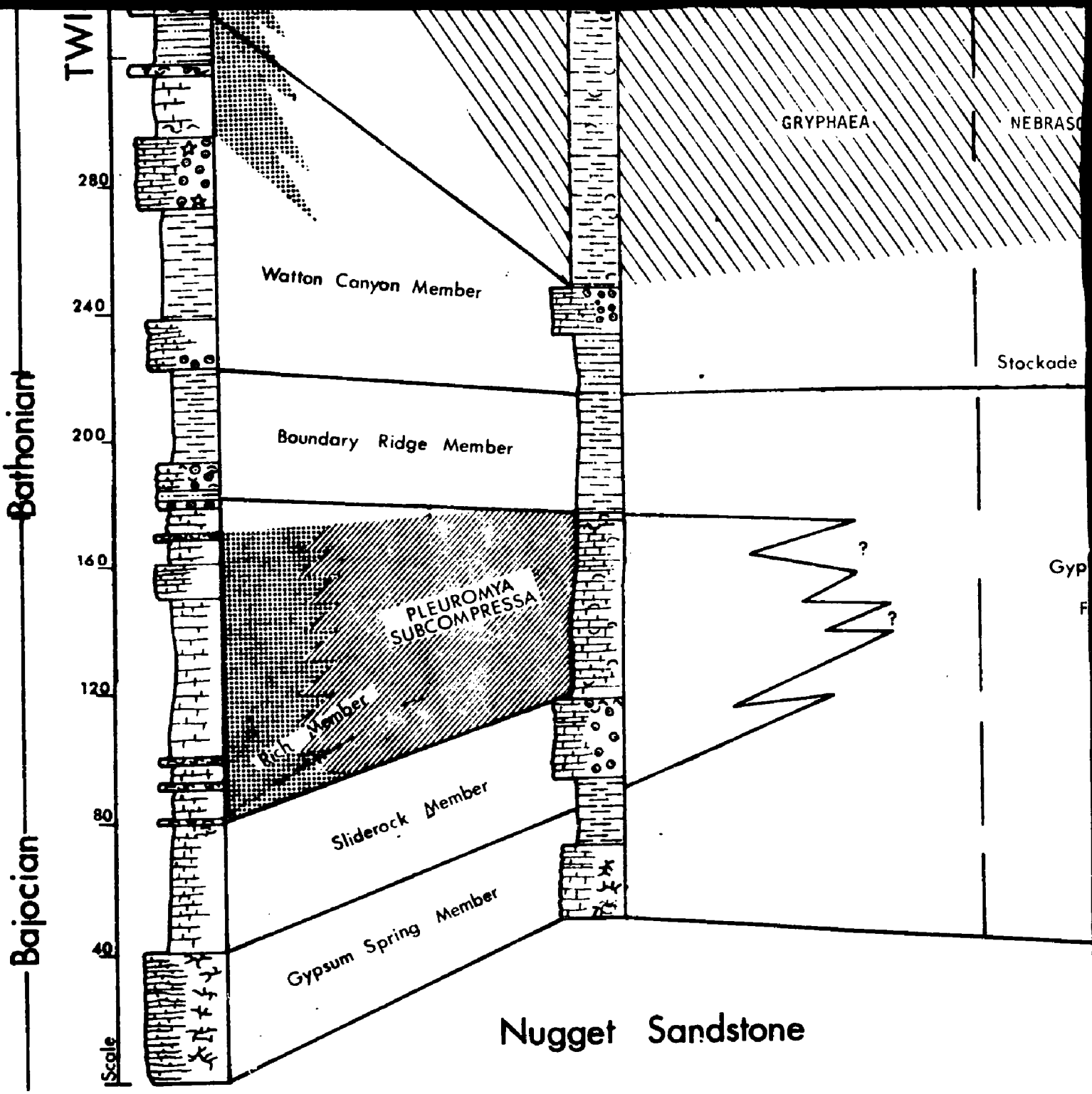
Jelm Formation

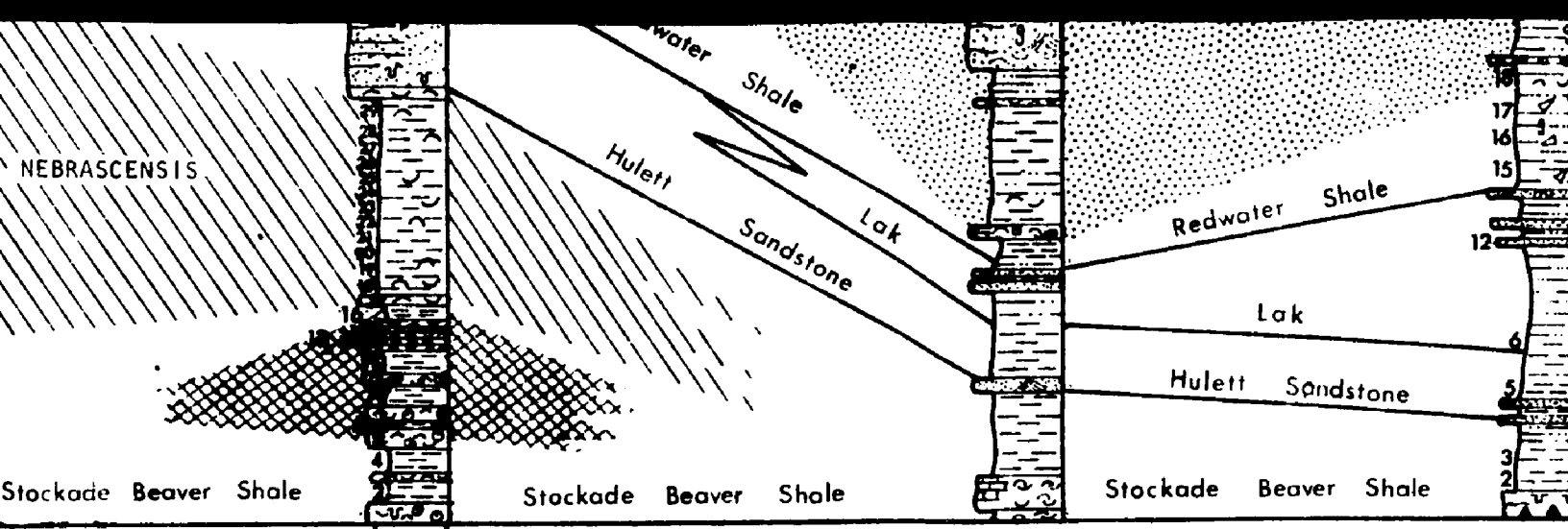



Pine Butte
Lak
Hulett Sandstone
MELEAGRINELLA
Stockade Beaver Shale
Canyon Spring Sandstone
Hulett Sandstone
CURTA
Stockade Beaver Shale
Canyon Spring Sandstone


Rapid City
6
X
X
4
1
X
3
X
2
X
Hot
Springs
SOUTH
DAKOTA

MINNEKAHTA
2
RAPID
CITY
4
Hulett Sandstone
Hulett Sandstone
CURTA
Stockade Beaver Shale
Stockade Beaver Shale
Canyon Spring Sandstone
C. S. S.
SUNDANCE FORM
Callovian
JURASSIC


TWI
280
240
200
160
120
80
40
Scale
Bathonian
Bajocian
GRYPHAEA
NEBRASC
Watton Canyon Member
Stockade
Boundary Ridge Member
PLEUROMYA SUBCOMPRESSA
Rich Member
Sliderock Member
Gypsum Spring Member
Gyp
?
?
Nugget Sandstone



Gypsum Spring Formation

Gypsum Spring Formation

LEGEN

LIMESTONE

CLAYSTONE OR SHALE

SILTSTONE

SANDSTONE

GYPSUM

GLAUCONITE

CHERT PEBBLES

OOLITES

CRINOID COLUMNALS

BIVALVES

BELEMNITES

CROSS BEDDING

BURROWS

BORED SURFACE

BORED COBBLES

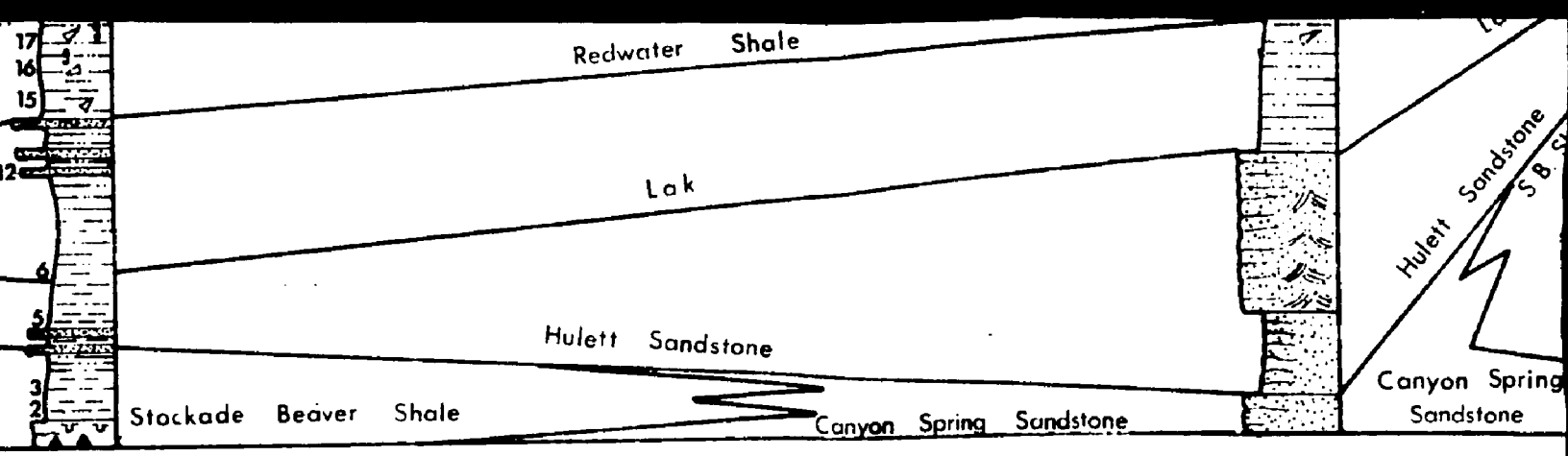
IRON NODULES

BRECCIA

Vertical Scale

Horizontal distance

numbers to the left of sections 6, 8, 9, 11, 12



Jelm

LEGEND

BIVALVE BIOFACIES

- CAMPTONECTES BELLESTRIATUS
- PLEUROMYA SUBCOMPRESSA
- TRIGONIA AMERICANA
- MELEAGRINELLA CURTA
- GRYPHAEA NEBRASCENSIS
- PRONOELLA CINNABARENSIS & PLEUROMYA SUBCOMRESSA
- CAMPTONECTES STYGIUS
- OSTREA STRIGILECULA

Scale 1" = 40'
distance not to scale
11, 12, 13, 16, and 20 indicate microfossil samples.

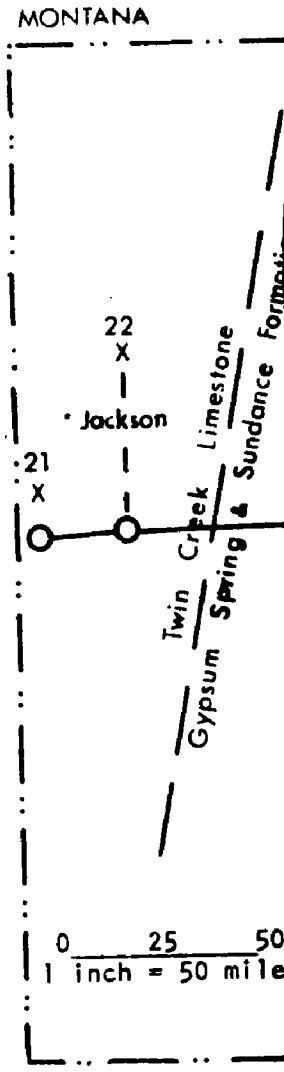
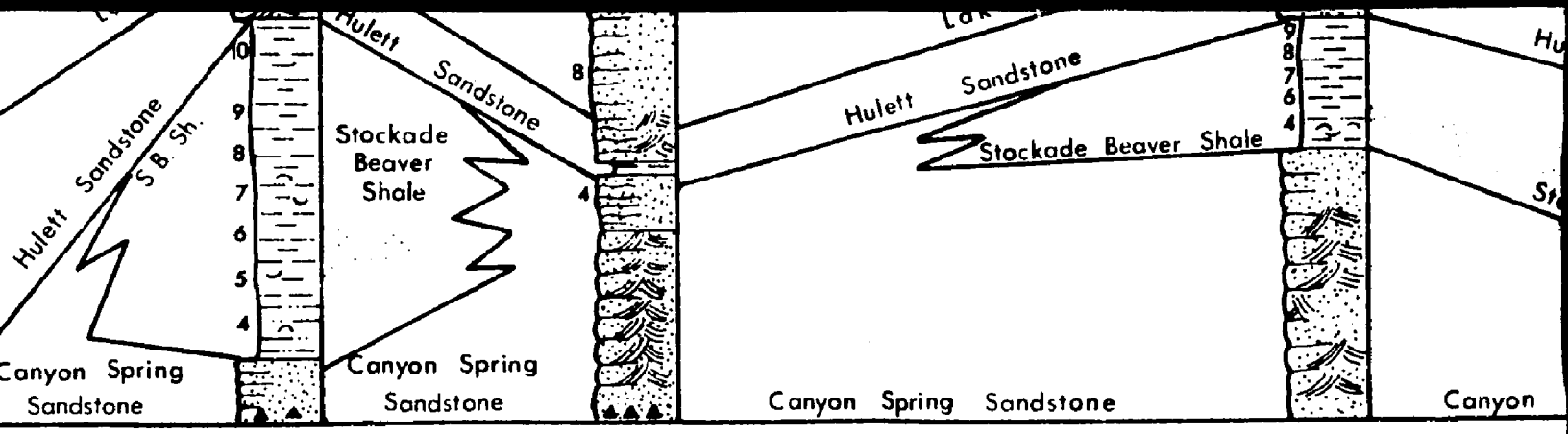
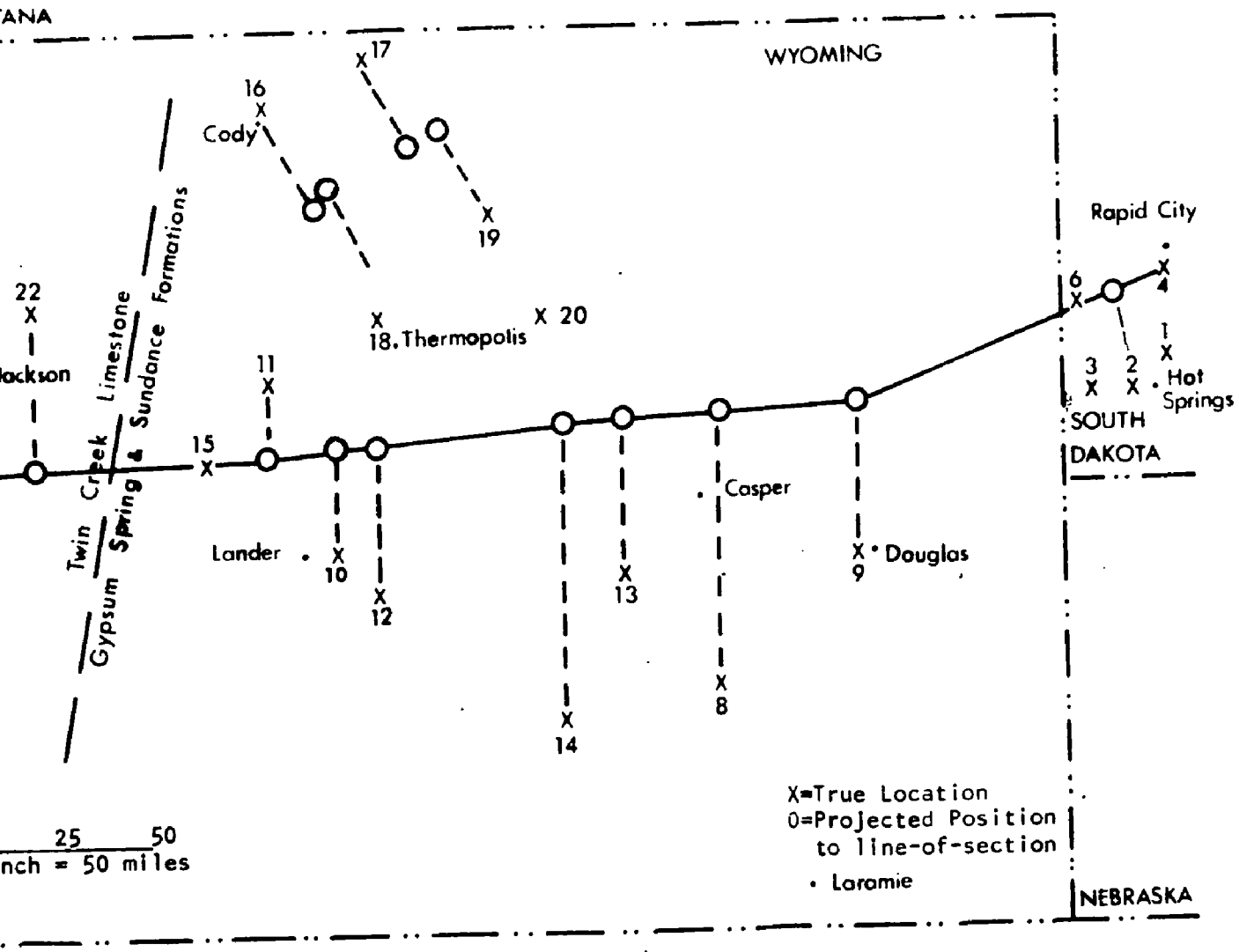


Plate 20. Stratigraphic diagram of middle and upper Jurassic deposits and biofacies in weste

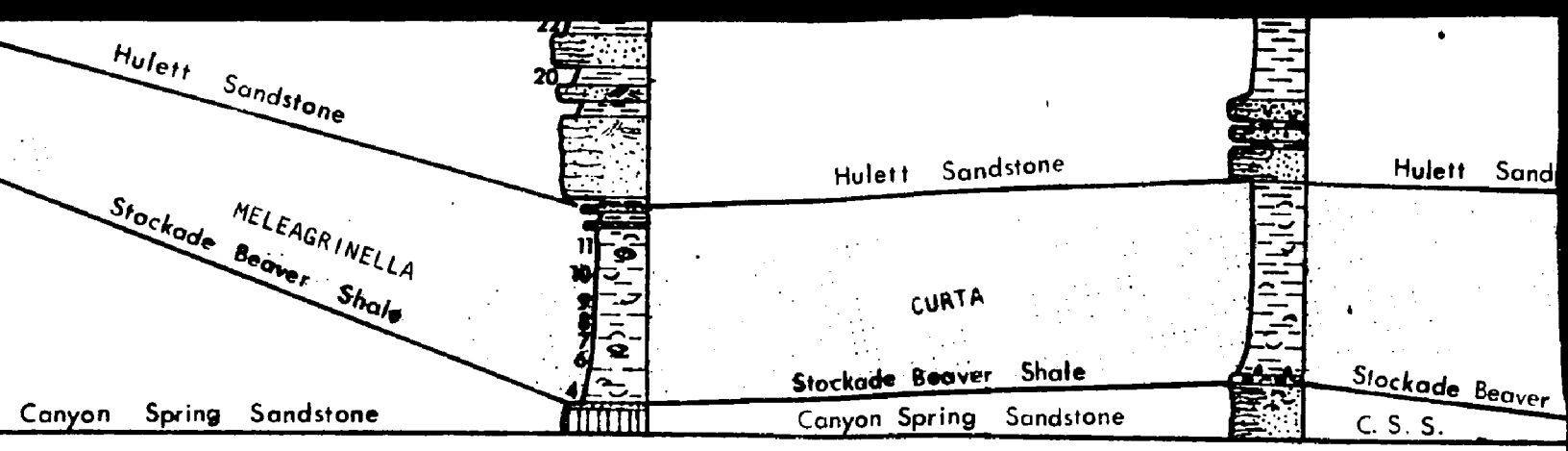


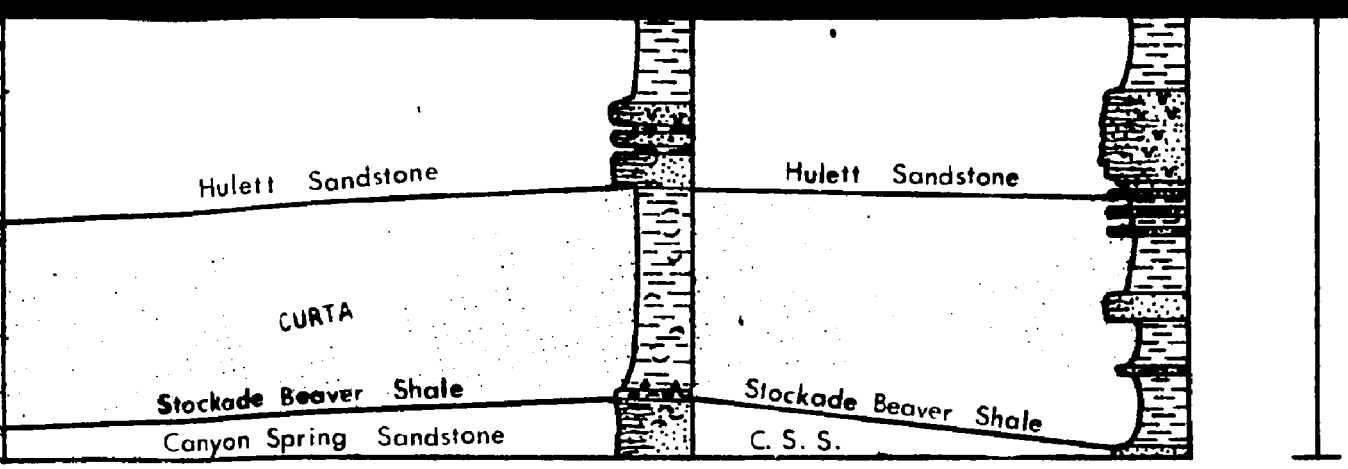
Jelm Formation

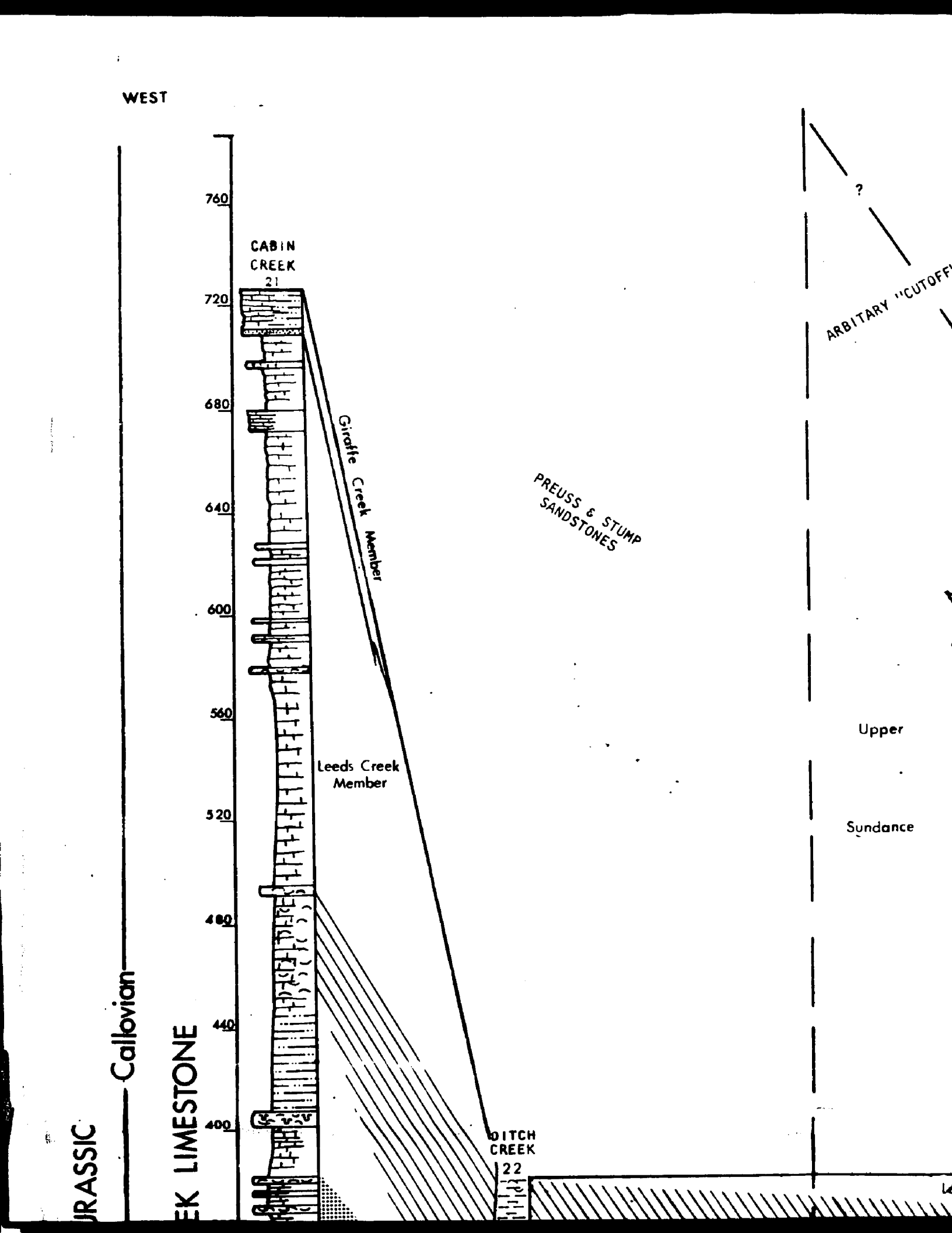


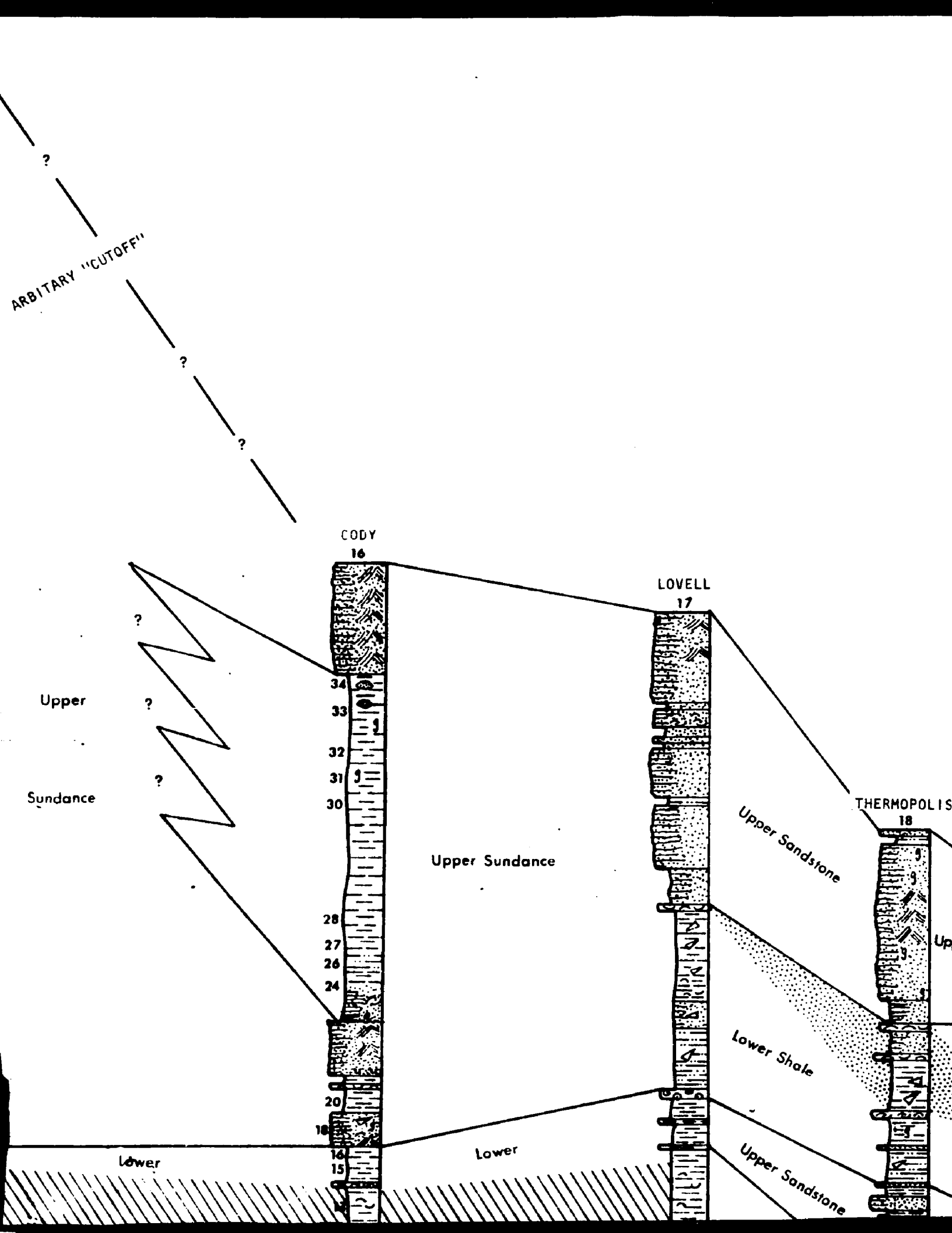
INDEX MAP SHOWING LOCATION OF STRATIGRAPHIC SECTIONS

cies in western, central and eastern Wyoming and South Dakota.

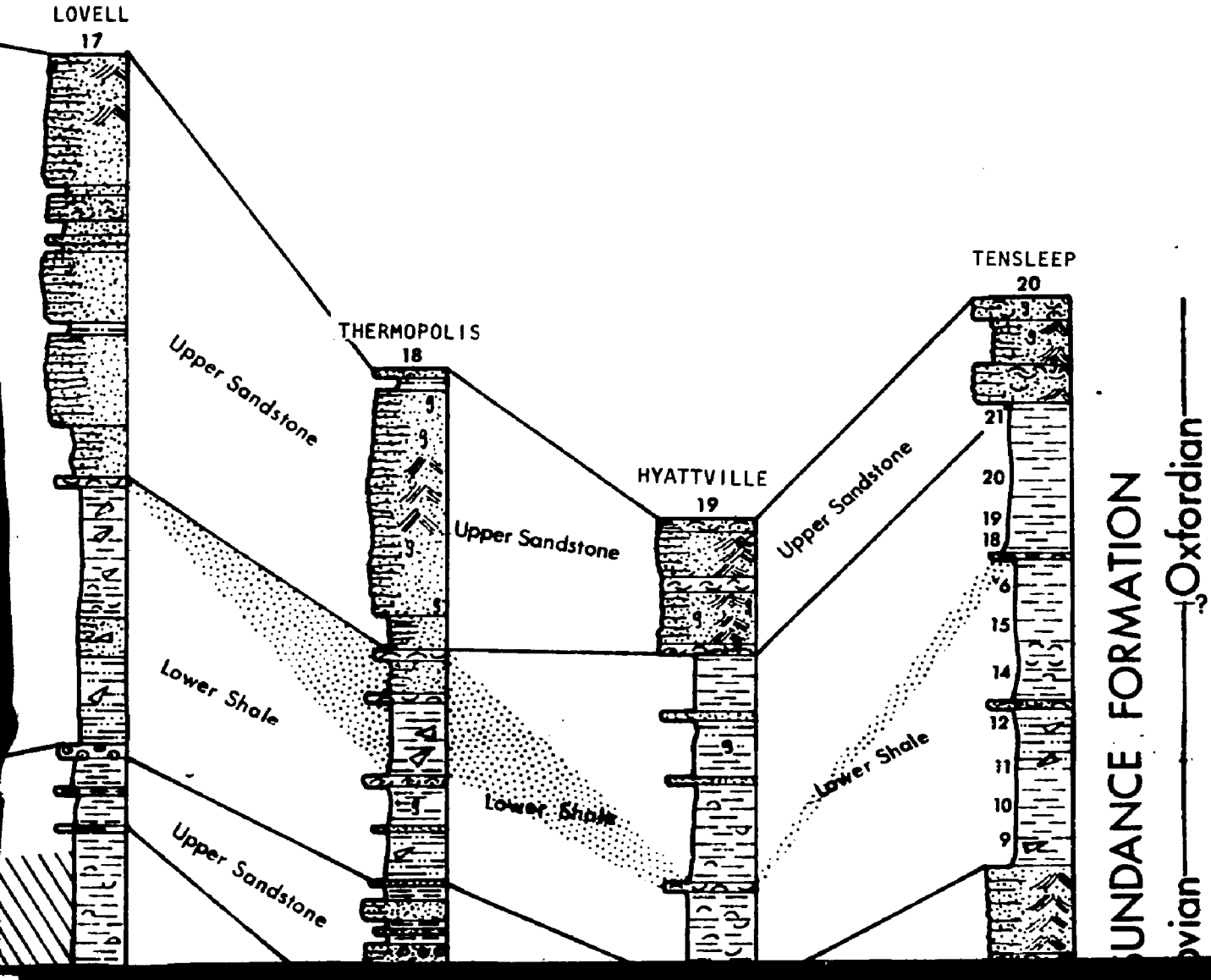

Hulett Sandstone
MELEAGRINELLA
Stockade Beaver Shale
Canyon Spring Sandstone
20
11
9
6
4
Hulett Sandstone
CURTA
Stockade Beaver Shale
Canyon Spring Sandstone
Hulett Sand
Stockade Beaver
C. S. S.

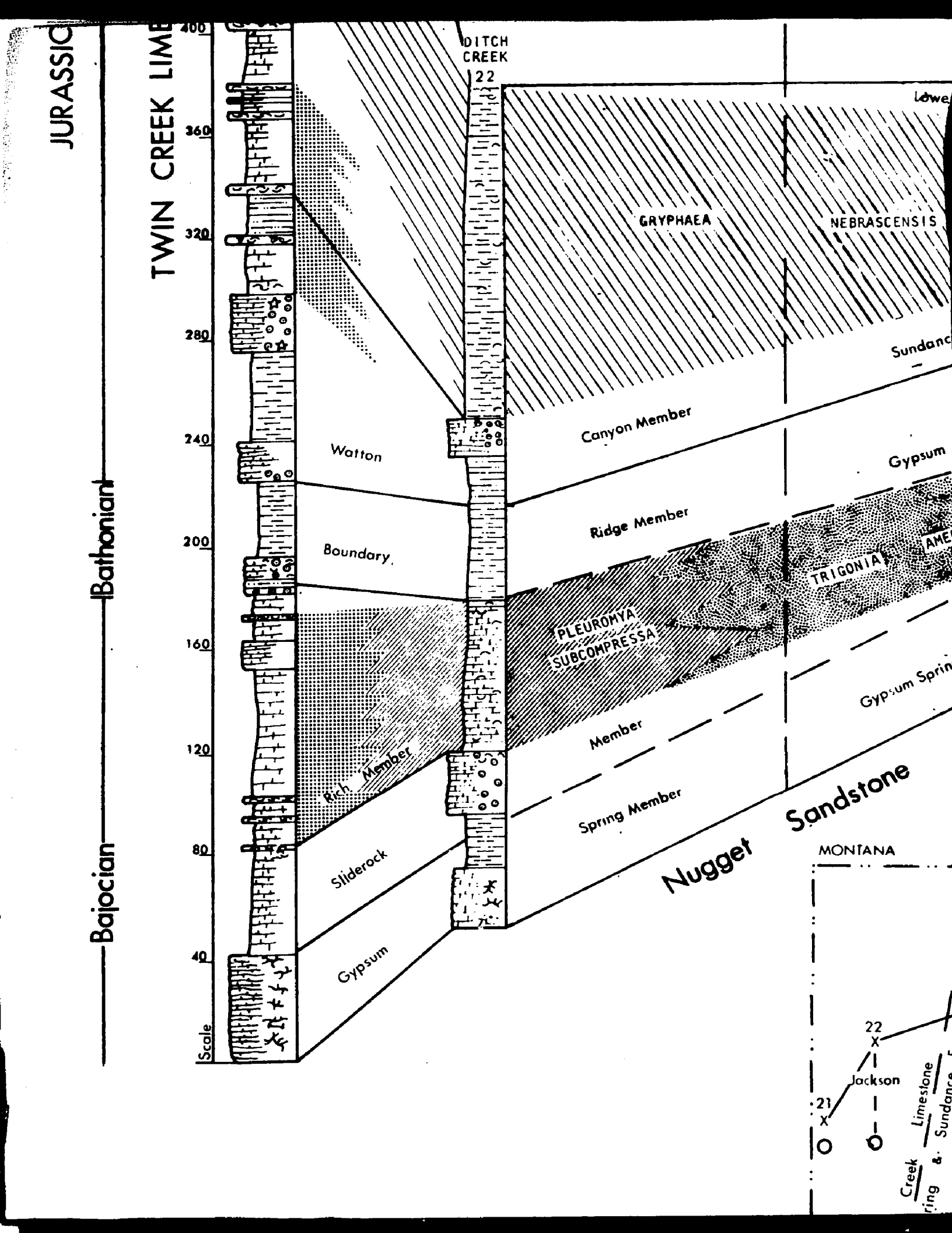

Hulett Sandstone
CURTA
Stockade Beaver Shale
Canyon Spring Sandstone
Hulett Sandstone
Stockade Beaver Shale
C. S. S.

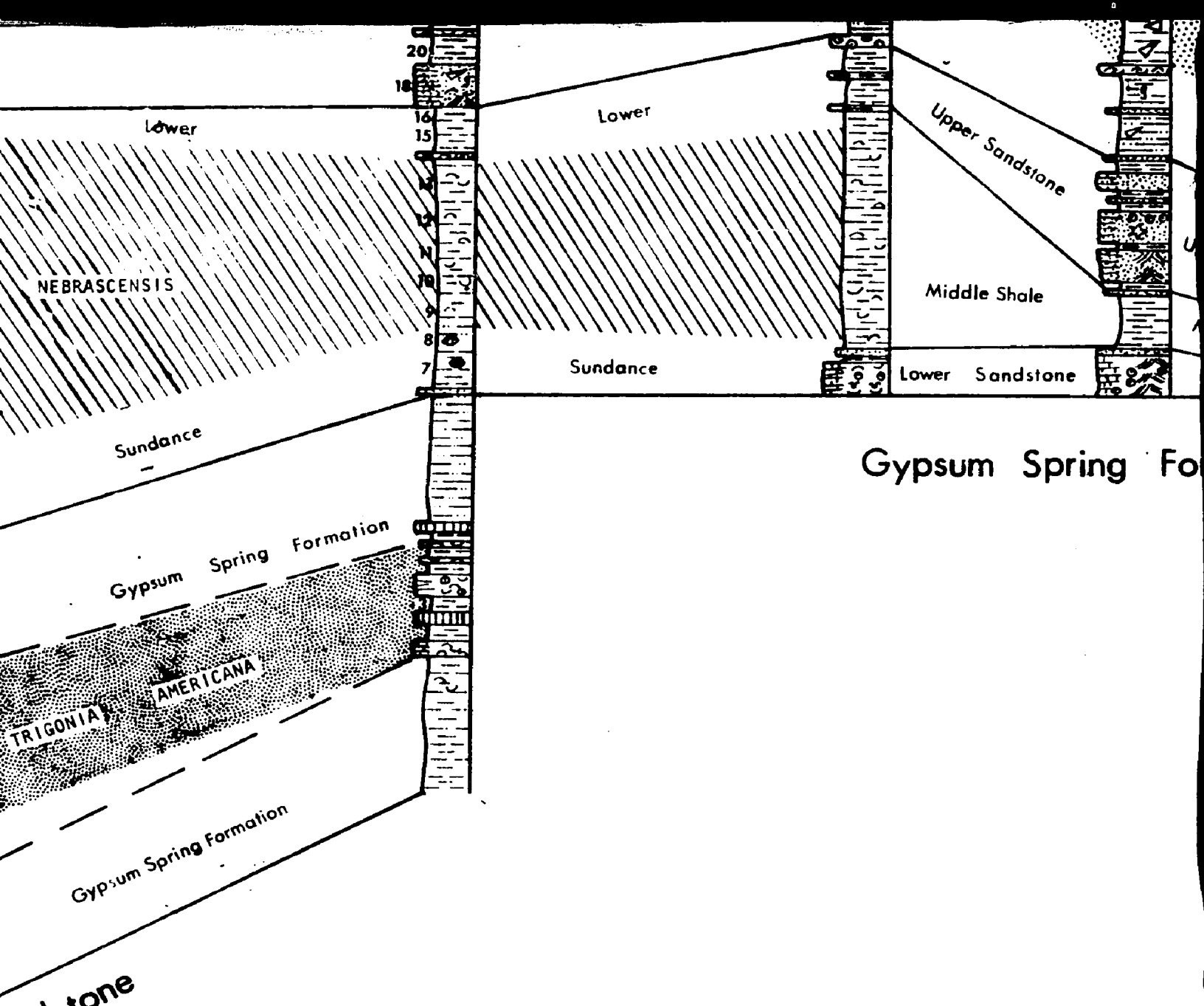

WEST
760
720
680
640
600
560
520
480
440
400
CABIN CREEK
21
Giraffe Creek Member
Leeds Creek Member
PREUSS & STUMP SANDSTONES
DITCH CREEK
22
?
ARBITARY "CUTOFF"
Upper
Sundance
Callovian
EK LIMESTONE
URASSIC

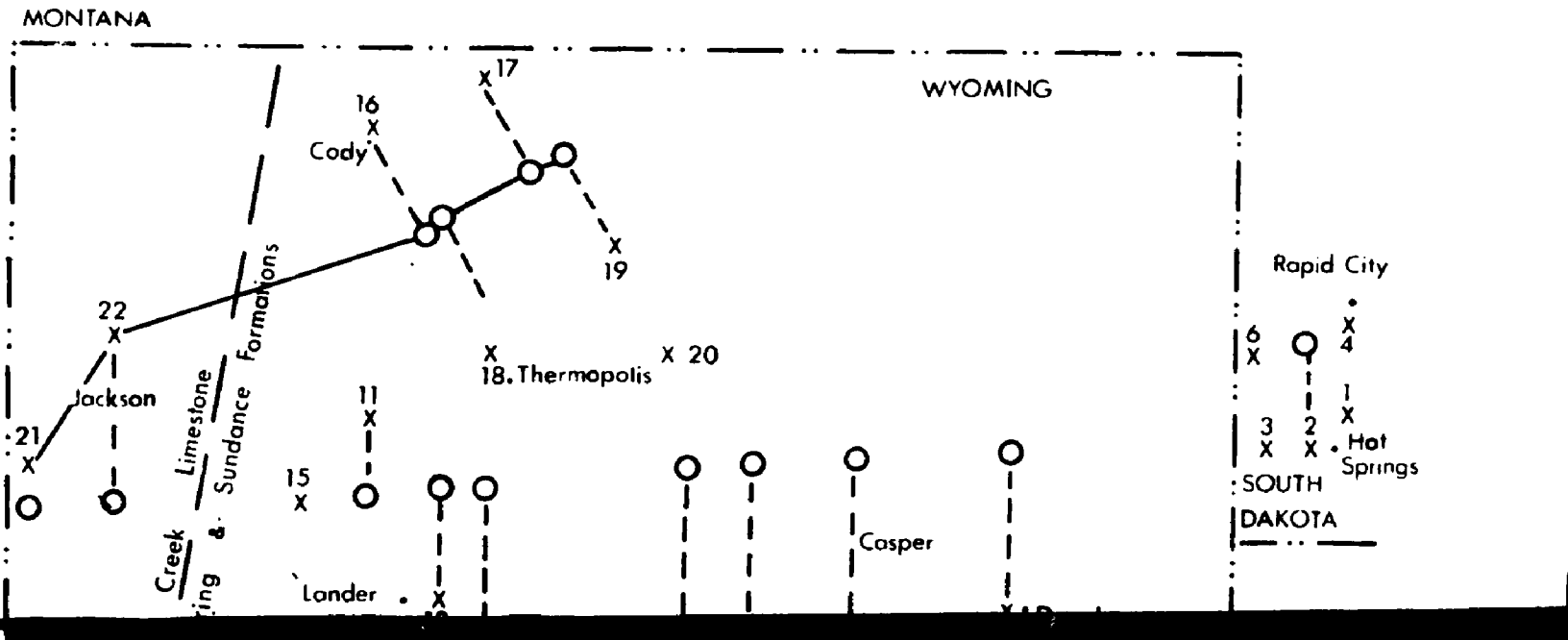

ARBITARY "CUTOFF"
?
?
?
CODY
16
LOVELL
17
THERMOPOLIS
18
?
?
?
Upper
Sundance
34
33
32
31
30
28
27
26
24
20
18
16
15
Upper Sundance
Lower
Lower
Upper Sandstone
Lower Shale
Upper Sandstone
Up

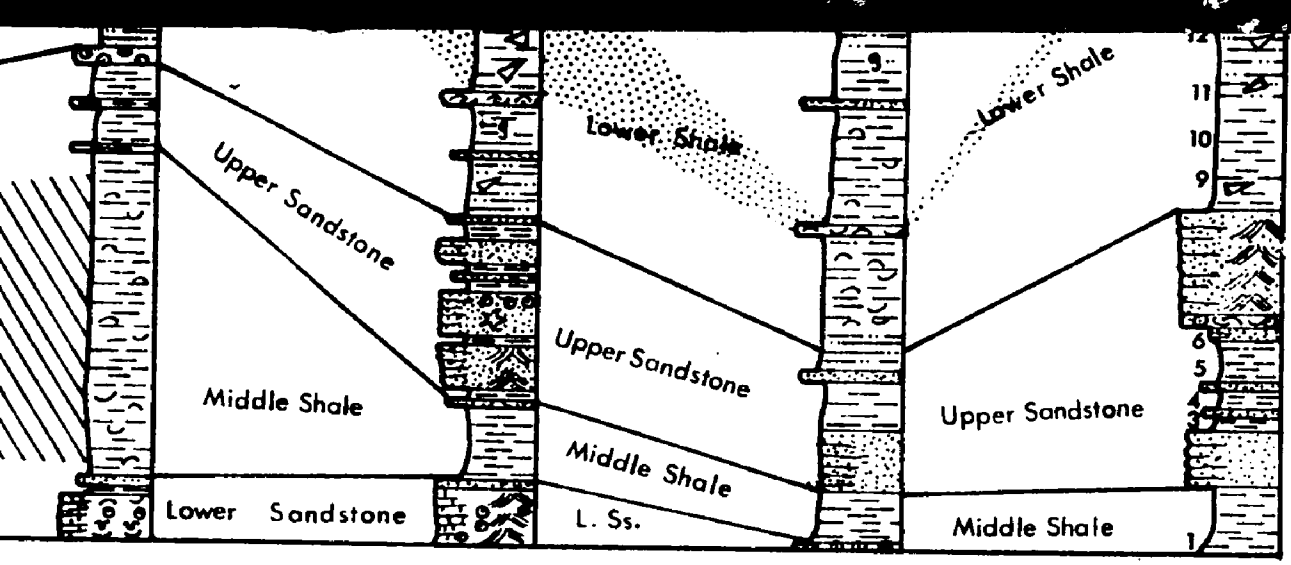
EAST


LOVELL
17
THERMOPOLIS
18
HYATTVILLE
19
TENSLEEP
20
Upper Sandstone
Upper Sandstone
Upper Sandstone
Upper Sandstone
Lower Shale
Lower Shale
Lower Shale
21
20
19
18
15
14
12
11
10
9
SUNDANCE FORMATION
Oxfordian?
JURASSIC


JURASSIC
Bajocian
Bathonian
TWIN CREEK LIME
400
360
320
280
240
200
160
120
80
40
Scale
DITCH CREEK
22
GRYPHAEA
NEBRASCENSIS
Lowe
Sundanc
Canyon Member
Watton
Gypsum
Ridge Member
Boundary
TRIGONIA
AME
PLEUROMYA SUBCOMPRESSA
Member
Gypsum Sprin
Rich Member
Spring Member
Slide rock
Gypsum
Nugget Sandstone
MONTANA
22
Jackson
21
Limestone
Creek
Sundance


Lower
NEBRASCENSIS
Sundance
Gypsum Spring Formation
TRIGONIA
AMERICANA
Gypsum Spring Formation
Lower
Upper Sandstone
Middle Shale
Sundance
Lower Sandstone
Gypsum Spring Fo
andstone


MONTANA
WYOMING
Cody
Jackson
Limestone
Sundance Formations
Creek
ing
Lander
18. Thermopolis
Casper
Rapid City
Hot Springs
SOUTH
DAKOTA

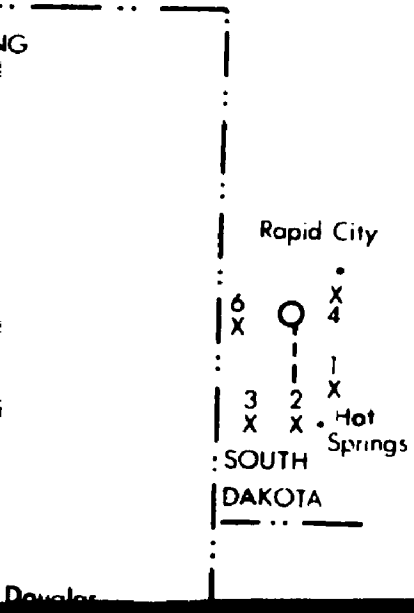


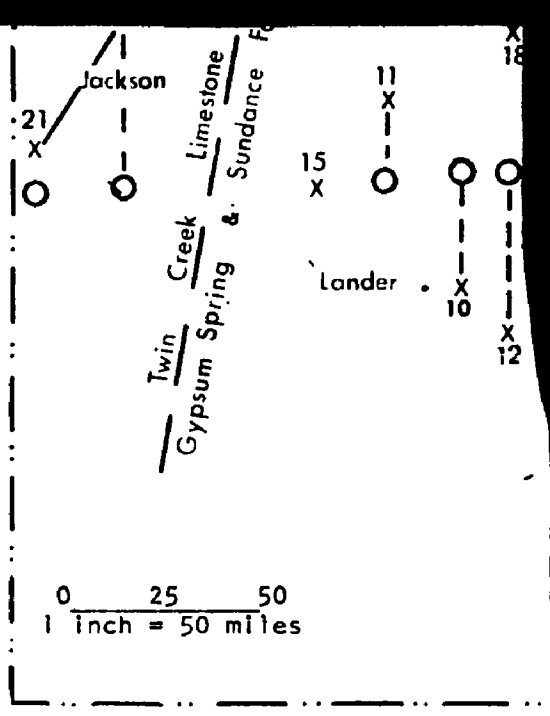
Gypsum Spring Formation

SUNDANCE

JURAS

—Bajocian—Bathonian—Callovian—





INDEX MAP SHOWING

LIMESTONE

CLAYSTONE OR SHALE

SILTSTONE

SANDSTONE

GYPSUM

GLAUCONITE

CHERT PEBBLES

OOLITES

CRINOID COLUMN

BIVALVES

BELEMNITES

CROSS BEDDING

BURROWS

BORED SURFACE

BORED COBBLES

IRON NODULES

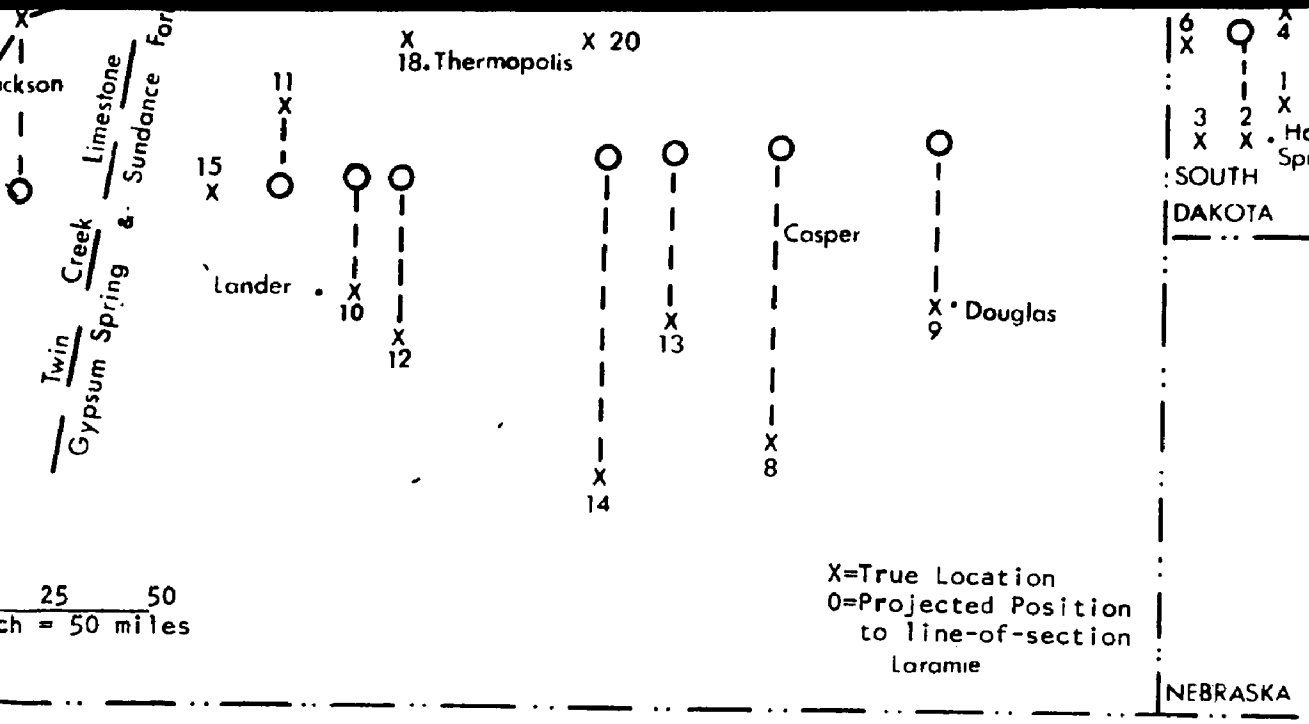
BRECCIA

Verti

Horizont

numbers to the left of sections 6, 8

Plate 21. Stratigraphic diagram of middle and uppe



INDEX MAP SHOWING LOCATION OF STRATIGRAPHIC SECTIONS

LEGEND

- GLAUCONITE
- CHERT PEBBLES
- OOLITES
- CRINOID COLUMNALS
- BIVALVES
- BELEMNITES
- CROSS BEDDING
- BURROWS
- BORED SURFACE
- BORED COBBLES
- IRON NODULES
- BRECCIA

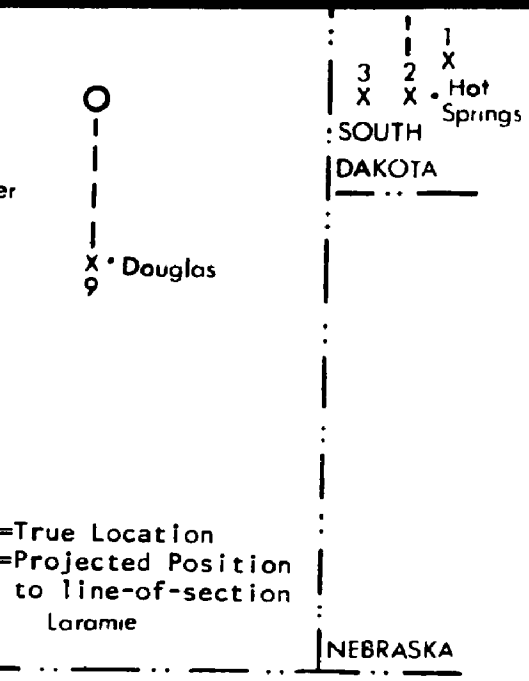
BIVALVE BIOFACIES

- CAMPTONECTES BELLESTRIATUS
- PLEUROMYA SUBCOMPRESSA
- TRIGONIA AMERICANA
- MELEAGRINELLA CURTA
- GRYPHAEA NEBRASCENSIS
- PRONOELLA CINNABARENSIS & PLEUROMYA SUBCOMRESSA
- CAMPTONECTES STYGIUS
- OSTREA STRIGILECULA

Vertical Scale 1" = 40'
Horizontal distance not to scale

to the left of sections 6, 8, 9, 11, 12, 13, 16, and 20 indicate microfossil samples.

c diagram of middle and upper Jurassic deposits and biofacies in western and northern Wyoming.



ECTIONS

BIVALVE BIOFACIES

CTES
ATUS

GRYPHAEA NEBRASCENSIS

PRESSA

PRONOELLA CINNABARENSIS &
PLEUROMYA SUBCOMRESSA

NA

CAMPTONECTES STYGIUS

ELLA CURTA

OSTREA STRIGILECULA

indicate microfossil samples.

facies in western and northern Wyoming.